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WORLD IRON-ORE MAP.

HARRY M. MIKAMI.

THE accompanying map [1] shows the distribution and relative sizes of the world's significant iron-ore deposits. The deposits are indicated according to the following sizes: (1) first magnitude, those containing one billion or more tons; (2) second magnitude, 100 million to one billion tons; and (3) third magnitude, those of less than 100 million tons. The deposits are further separated into actual reserves and potential reserves. Under actual reserves are included those which because of their size, tenor, composition, and location constitute an economically available source of iron ore. By potential reserves are meant those reserves which, from a consideration of the same factors or any combination of those factors, cannot at present be exploited. Most of the first magnitude actual reserves of the world are accompanied by first magnitude potential reserves of lower grade and/or ore not readily accessible, *e.g.*, Lake Superior district, Wabana, England, Lorraine, Minas Gerães, and others. Symbols for all of these potential reserves, however, could not conveniently be placed on the map.

To obtain accurate estimates of tonnages from all parts of the world, or even from this country for that matter, is very difficult. The estimates for the better known districts which have been worked for a long time such as Lake Superior, Sweden, Lorraine, etc., are for the most part reliable and probably conservative.

[1] The base map used is a Mercator projection prepared by Henry M. Leppard and published by the University of Chicago Press.

Less developed deposits are estimated less certainly and perhaps often, optimistically. The figures for the tonnages include *proved* and *probable* ore; as far as feasible *possible* [2] ore was excluded. In the case of little developed deposits such classification of ores is often arbitrary and subjective. However, geologic theory tends to temper the judgment of even the most sanguine estimators. For example, a lateritic deposit outcropping over a large area with a known representative thickness can with reasonable assurance be given a large estimate of probable ore even though rather sparsely drilled, whereas contact metasomatic deposits are judged with caution and their size is usually comparatively small. It is also difficult to present graphically the comparative commercial importance of the various reserves because of the great differences in distance from markets or from coking coal supplies (or both), and because of the considerable disparity in the amount of reliable information concerning them.

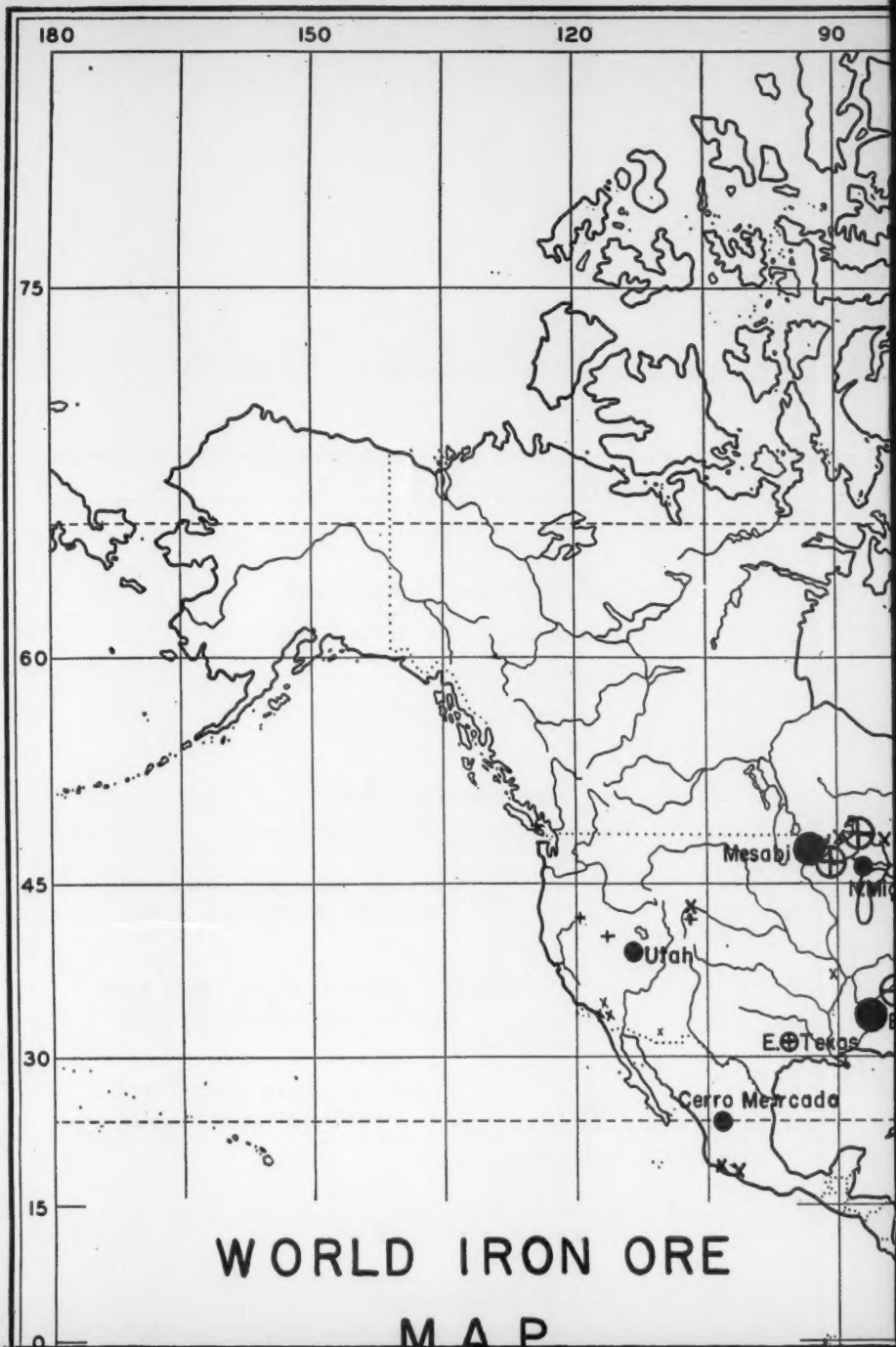
ANNOTATED BIBLIOGRAPHY.

The majority of the figures for tonnages were taken from the literature of the last ten years although this was not possible for all the deposits. In some instances where little or no mining has taken place, or in the case of large deposits with moderate production, older estimates have not been greatly affected by depletion and were used if newer or better ones were not available.

Neither the map nor this list is an inventory of every known iron-ore deposit; many minor ones are not included, as a comparison with the Stockholm report (1910), Roesler, Hodge, or Kuhn (see General References, below) will make apparent. However, some of these minor reserves of only a few million tons, *e.g.*, some in California, are included because of their actual or probable importance to a local market.

Many other references than those listed here were consulted and were used to compare with, and in some instances to modify somewhat, the figures given in this list.

[2] By *possible* is meant "of uncertain existence" and not in the dictionary sense in which it is synonymous with potential.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Mesabi
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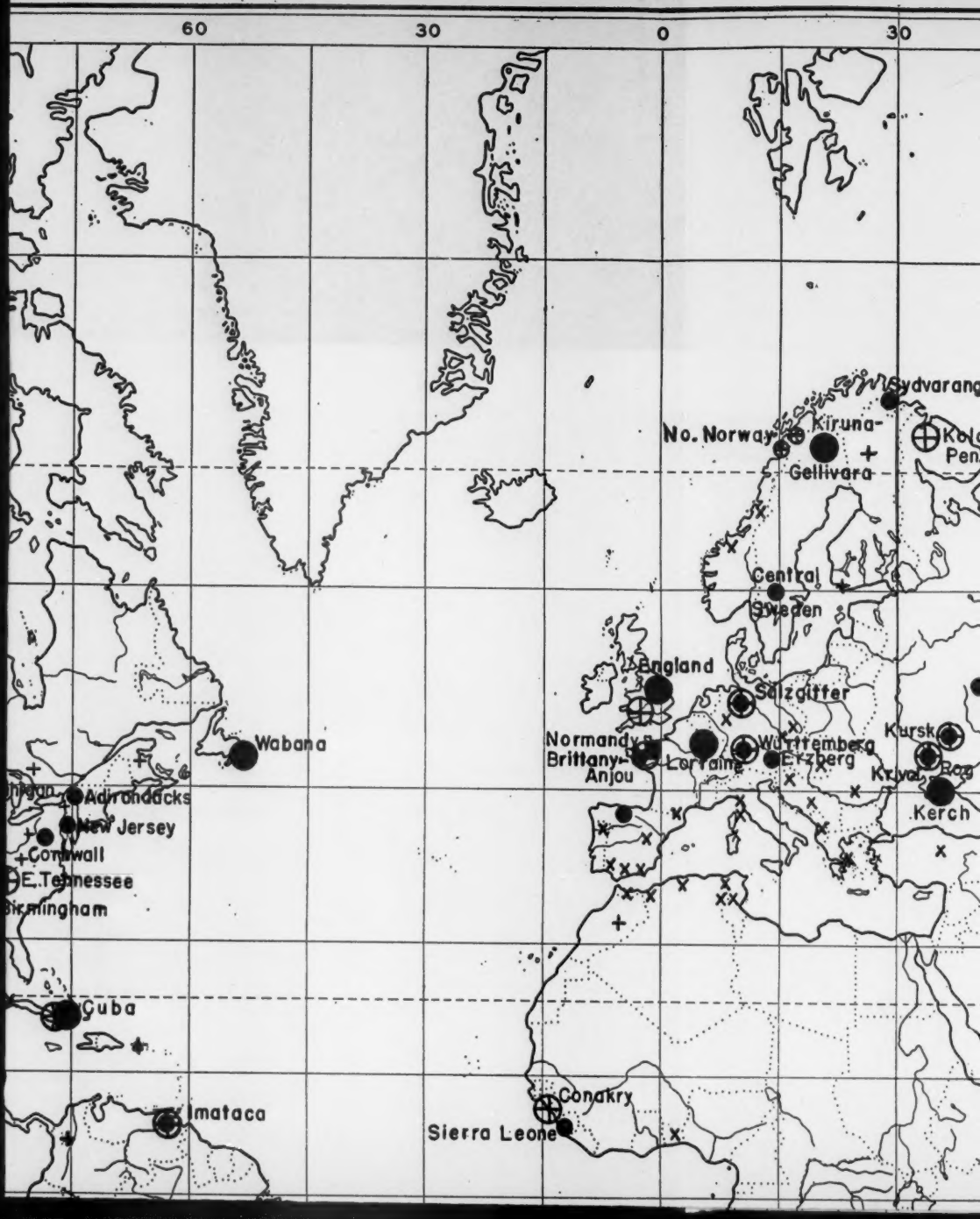
WORLD IRON ORE
MAP


60
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Kydvarang
No. Norway
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Wabana
Normandy
Brittany-
Anjou
Lorraine
Württemberg
Erzberg
Kursk
Kerch
Adirondacks
New Jersey
Cornwall
E. Tennessee
Birmingham
Cuba
Imataca
Conakry
Sierra Leone

30
60
90
Sydvaranger
Kiruna-
Gellivara
Kola
Pen.
Sverdlevsk
Bakal
Magnitogorsk
Orsk
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Region
Tula
Lipetsk
Chorjor
Kursk
Karatsch
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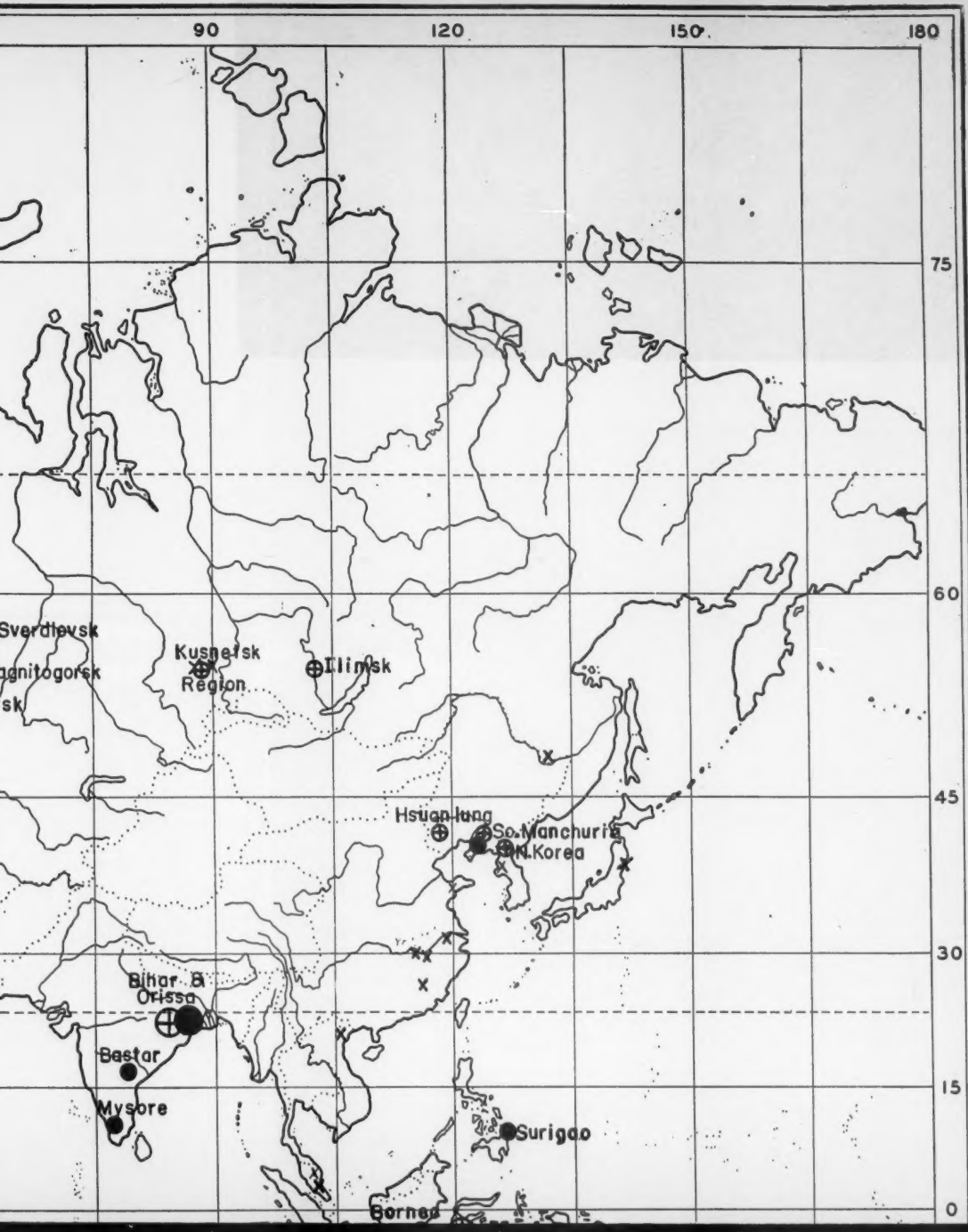
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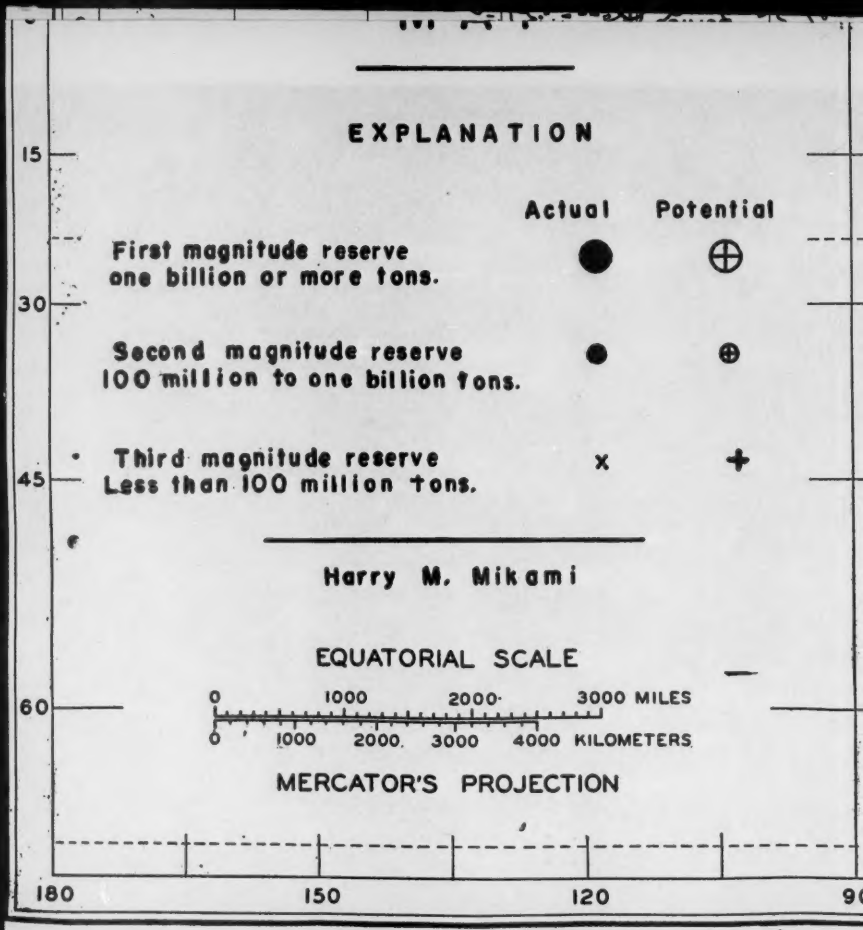
EXPLANATION
Actual
Potential
First magnitude reserve
one billion or more tons.
Second magnitude reserve
100 million to one billion tons.
Third magnitude reserve
Less than 100 million tons.
Harry M. Mikami
EQUATORIAL SCALE
0 1000 2000 3000 MILES
0 1000 2000 3000 4000 KILOMETERS
MERCATOR'S PROJECTION
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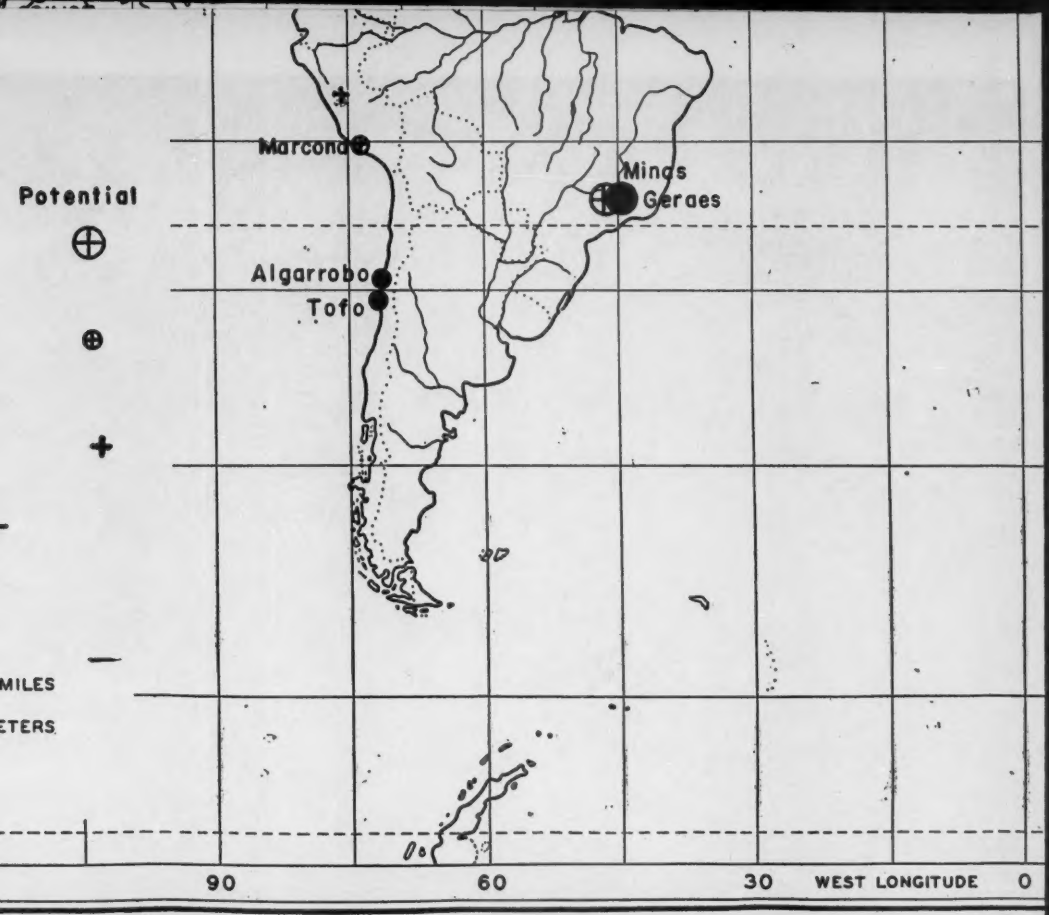
Potential
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Minas
Geraes
Algarrobo
Tofo
MILES
ETERS
90
60
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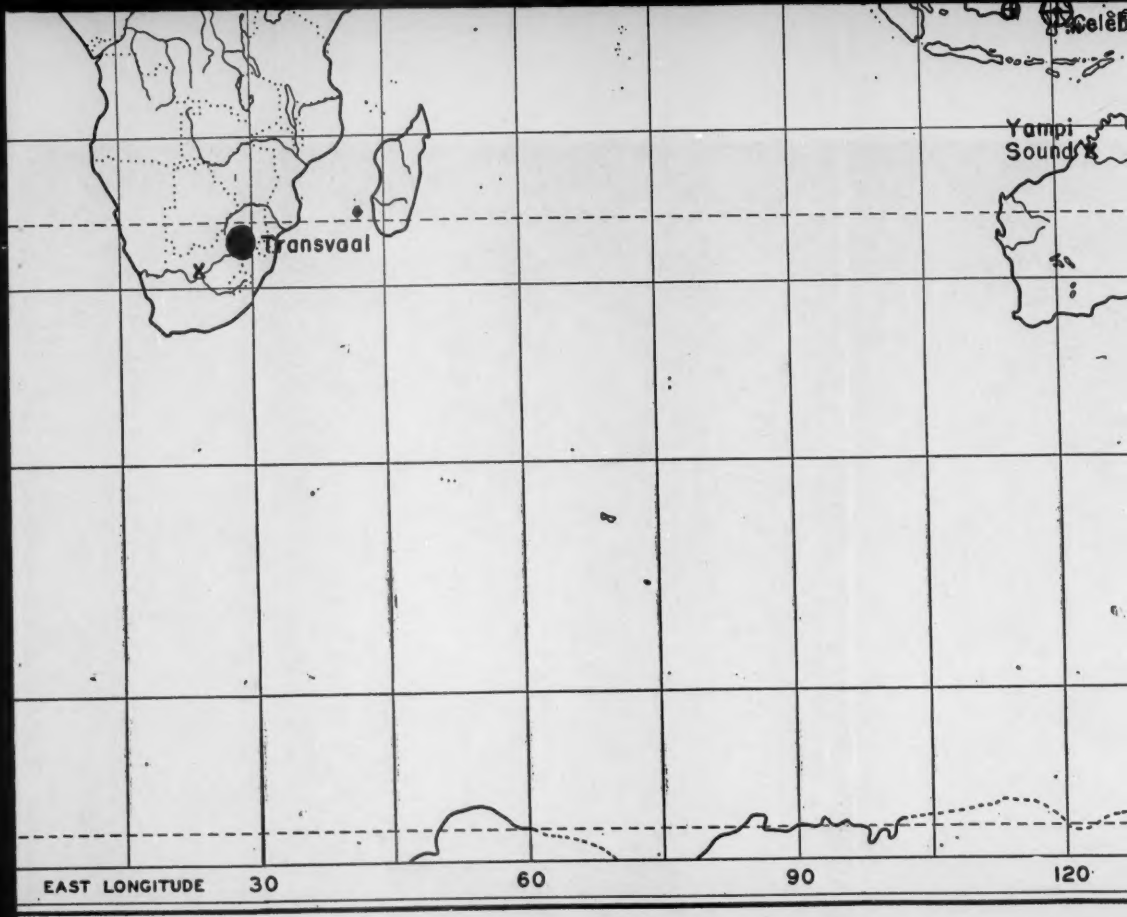
WEST LONGITUDE
0


Transvaal
Yampi Sound
EAST LONGITUDE
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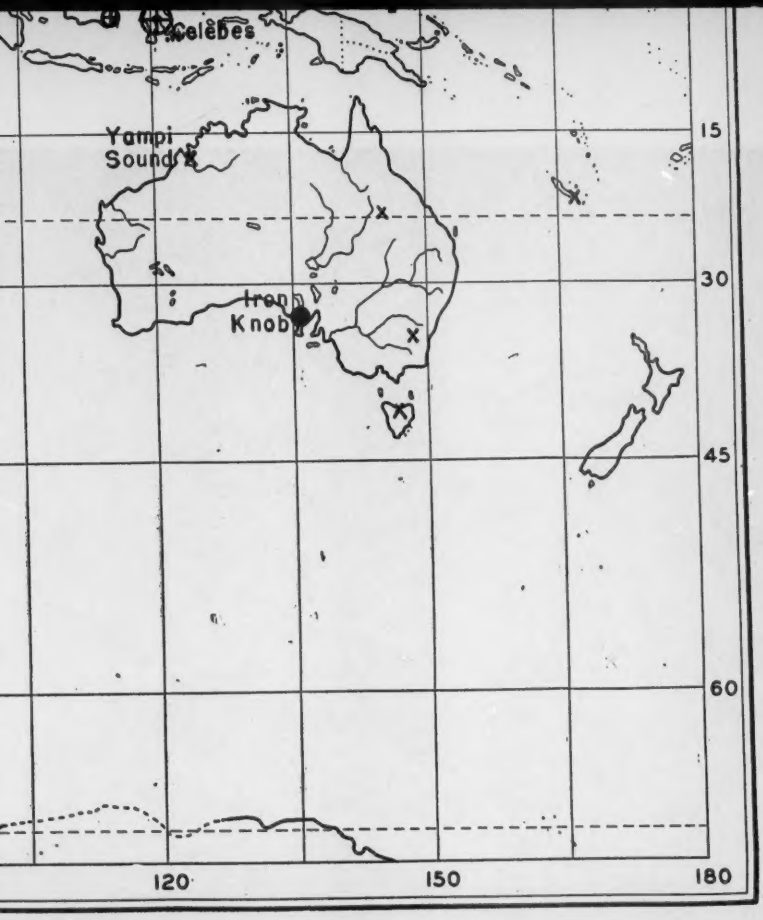
90
120


Celebes
Yampi
Sound
Iron
Knob
15
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45
60
120
150
180

NORTH AMERICA.

CANADA:

Steeprock Lake, Ontario: 25 million tons, 60–62% Fe. Ref.: H. M. Roberts and M. W. Bartley, Hematite deposits, Steeprock Lake: Mining Technology, Tech. Publ. 1543, Jan. 1943. Development is in an early stage, promise of larger tonnage seems indicated.

Helen range, Michipicoten, Ont.: 69 million tons, 35–45% Fe. Siderite. Ref.: W. H. Collins, T. T.Quirke, and E. Thompson, Michipicoten Iron Ranges: Mem. Geol. Surv. Can. 147, p. 83, 1926.

Moose Mountain mine; Sudbury dist.: Potential. 38 million tons, 35% Fe. *Austin Brook, N. B.:* Potential. 18 million tons, 45% Fe. Ref.: E. Lindeman and L. L. Bolton, Iron ore occurrences in Canada: 2 vol. Can. Dept. Mines, Mines Branch no. 217, 1917.

Texada Island, B. C.: 1½ million tons, 60% Fe., potential. Ref.: G. A. Young & W. L. Uglow, Iron ore in B. C. and Yukon: Geol. Surv. Can. Econ. Geol. series no. 3, 1926.

CUBA:

Moa: 1,500 million tons, av. 40% Fe. *Mayarí:* 600 million tons, 90% of this over 40% Fe. *San Felipe:* 400 million tons, 40% Fe., 50 million tons, 45% Fe. *Levisa:* 75 million tons, 45% Fe. *Santiago:* 4 million tons, 55–65% Fe. These are in *eastern Cuba.*

Pinar del Rio, western Cuba: 40 million tons, 40% Fe.

Total actual reserves of Cuba are estimated at about three billion tons. Potential reserves of lower grade ore are put at about 12 billion tons. The total production of iron ore in Cuba from 1884 through 1940 is about 27 million tons; about two-thirds of this came from the Daiquiri and Juragua mines of the Santiago field. Ref.: O. R. Kuhn, Iron-ore deposits of Cuba; Eng. Min. Jour. 121 (15): 607–610, 1926; Minerals Yearbook, rev. of 1940, p. 538, 1941.

MEXICO:

Cerro Mercado, Durango: 100 million tons, 60% Fe. Ref.: W. F. Foshag, Geology of Cerro Mercado: U. S. Nat. Mus. Proc. 75, art. 23, 1929.

Las Truchas, Michoacán: 10 million tons, 60% Fe. *El Mamey, Colima:* 24 million tons, 65% Fe. *Zaniza, Oaxaca:* 20 million tons. (These three potential.) Ref.: T. Flores, Yacimientos Minerales de Mexico: Inst. Geol. Mex. fol. div. no. 38, Dec. 1932, (1933).

NEWFOUNDLAND:

Wabana, Conception Bay: 1,250 million tons, 40% Fe, recoverable. Probably several billion tons potential. Ref.: A. O. Hayes, Structural geology of Conception Bay: ECON. GEOL. 26: 44–64, 1931.

UNITED STATES:

Lake Superior region: Total actual ore, 1,340 million tons, av. 50–55% Fe. The individual deposits of the region are: *Mesabi,* 1,123 million tons; *Vermilion,* 13 million tons; *Cuyuna,* 65 million tons; *Gogebic,* 31 million tons; *Marquette,* 48 million tons; *Menominee,* 55 million tons. The first three are in *Minnesota,* the last three in *Michigan.* The portion of the Gogebic range in *Wisconsin* has about 5 million tons. Ref.: Minerals Yearbook for 1940, p. 542, U. S. Bur. Min. 1941 (quoting Minnesota and Michigan tax commissions).

As for *potential Lake Superior* ores there are about 60 billion tons of siliceous ores with 35%-or-better Fe. (Van Hise and Leith, U. S. Geol. Surv. Mon. 52, p. 492, 1911.) In the *eastern Mesabi* range are several billion tons of 20–30% magnetite ore which can be readily concentrated. Ref.: F. F. Grout and T. M. Broderick, Magnetite deposits of eastern Mesabi: Minn. Geol. Surv. Bull. 17, 1919; A. B. Parsons, Operations of the Mesabi Iron Co.: Eng. Min. Jour. 117 (4): 157–167, 1924.

Birmingham district, N. Alabama: 1,400 million tons, 35% Fe actual; about 500 million tons second grade ore, potential. Ref.: E. F. Burchard, 16th Int. Geol. Cong. Guidebook 2, pp. 121–122,

1932. Thinner bedded, now unminable ore of various grades may boost the potential reserve into the first magnitude category.

New York State: Lake Sanford, Adirondacks, 15 million tons proved, titaniferous magnetite, 35–60% Fe, 15% TiO_2. Mined for TiO_2 and iron. Ref.: I. D. Haggar, Min. and Met. 23 (432): p. 596, 1942. The Lake Sanford district titaniferous magnetites were estimated to contain "at least 90 million tons" actual ore and 100 million tons potential ore by C. W. Hayes, Mineral Resources: U. S. Geol. Surv. Bull. 394, p. 83, 1909. The *non-titaniferous magnetite* ore of the *Adirondacks* probably total about 100 million tons of better-than-35% ore. The potential ore of this category is probably measured by the hundreds of millions of tons. H. M. Roche states that an average of various estimates of the non-titaniferous magnetites of New York (presumably including southern New York) is 900 million tons of 40–60% Fe ore (Iron Age 139:42, Feb. 18, 1937).

The *Clinton ores of New York* amount to 600 million tons of 35–45% Fe (potential) ore . Ref.: C. W. Hayes, U. S. Geol. Surv. Bull. 394, p. 87, 1909 (30 million tons listed as actual ore).

N. W. New Jersey: 600 million tons, 40–60% (av. 45%) Fe are said to be available. Magnetite ore which can be concentrated to 67% Fe. Ref.: H. M. Roche, New Jersey Iron Ore: Iron Age 139, p. 76, Feb. 4, 1937; W. S. Bayley, N. J. Geol. Surv. 7, 1910.

Pennsylvania: Cornwall, about 100 million tons, 40–50% Fe. Ref.: W. O. Hickok IV, Iron ore deposit at Cornwall: Econ. Geol. 38: 193–255, 1933 (does not give tonnage estimate). Potential reserves of *Clinton ore* amount to about 50 million tons, while potential reserves of Appalachian *carbonate ore* (*W. Penna.*) total about 45 million tons, 30–35% Fe. Ref.: C. W. Hayes, Mineral Resources: U. S. Geol. Surv. Bull. 394, p. 90, 95, 1909.

Ohio: 200 million tons, 30–35% Fe carbonate ore, potential.

Chattanooga district of S. E. Tennessee, N. W. Georgia, and N. E. Alabama: Potential reserve of Clinton ore amounts to about 500 million tons. The actual reserve may be a few tens of millions tons, mainly in Georgia.

In *northeastern Tennessee* in the Cumberland mountain district,

Burchard estimates a reserve (potential) of Clinton ore of 1,250 million tons; average thickness is four feet.

In the *Appalachian regions of Kentucky, West Virginia, Virginia, and North Carolina* there are potential low grade reserves of Clinton (mainly), carbonate, and brown ores aggregating about 400 million tons.

Ref.: C. W. Hayes, Mineral Resources: U. S. Geol. Surv. Bull. 394, 1909; E. F. Burchard, Red iron ore of eastern Tennessee: Tenn. Geol. Surv. Bull. 16, 1913.

East Texas: 139 million tons "probably available," 40–50% Fe. 37 million tons "possibly available." Ref.: E. B. Eckel, Brown iron ores of eastern Texas: U. S. Geol. Surv. Bull. 902, 1938.

Missouri: Iron Mountain and Pilot Knob (the latter ceased iron production in 1929). Probably a few million tons actual ore, the potential ore reserve may be larger.

Wyoming: Iron Mountain, 44 million tons, 50% Fe, 27% TiO_2, A potential reserve of titaniferous magnetite estimated to contain 113,000 tons per foot of depth. Ref.: R. A. Riemer, Titaniferous magnetite deposits of the Laramie Range, Wyo.: Geol. Surv. Wyo. Bull. 31, 1941. *Sunrise, Platte Co.:* no estimates are available; however, the reserve appears to be about 20–30 million tons at least, of actual ore. The iron content is about 55%. Production in 1940 was 831,000 tons. Ref.: G. H. Rupp, Mining Tech. Tech. Publ. 1069, 1939 (describes mining methods and some geology; no estimates).

Utah: Iron Springs and Bull Valley area, 100 million tons, 45–55%Fe. Ref.: F. G. Wells, Iron ore deposits of Bull Valley and Iron Springs: Econ. Geol. 33: p. 499, 1938.

California: Eagle Mountains, 75 million tons, 50% Fe. Ref.: E. C. Harder, Iron ore deposits of the Eagle Mountains: U. S. Geol. Surv. Bull. 503, 1912. *Ship Mountain, San Bernardino Co.,* 9 million tons, 60–65% Fe; *Minaret, Madera Co.,* 1 million tons, 64% Fe. Ref.: E. T. Hodge,[3] 1935, App. E–5. *Iron Mountain, San Bernardino Co.,* 10 million tons, 50–60% Fe. Ref.: Calif. Jour. Min. and Geol. vol. 36, p. 241, 1940. *Coso, Inyo Co.* 3

[3] If definite reference is not given, see under General References.

million tons, 60% Fe; Le Cyr, Inyo Co., 1.3 million tons, 60% Fe. Ref.: Idem, vol. 34, p. 425, 1938.

Other western states deposits containing potential reserves are the *Barth* and *Dayton* deposits of *Nevada,* and *Iron Mountain,* in *southern Idaho,* each believed to contain several million tons of about 60% Fe ore. There are small deposits of magnetite in the *Fierro district, New Mexico,* once an active producer though in recent years unproductive.

Puerto Rico: The *Mayaguez* limonite deposit has a potential reserve which according to Meyerhoff "may exceed 200 million tons." There are also magnetite deposits near Humacao of smaller size (estimates range from 350,000 to 20 million tons). Ref.: H. A. Meyerhoff, Geology of Puerto Rico: Univ. Puerto Rico Mon. ser. B, no 1, 281 pp., 1933, p. 136; Colony and Meyerhoff, A. I. M. E. Tech. Publ. 587, 1935.

EUROPE.

ALBANIA:

20 million tons of "high grade" hematite have been reported. Ref.: Albanian mineral resources: Ir. Coal Tr. Rev. 139, p. 676, 1939.

CZECHOSLOVAKIA:

Nucice and Beroun district, Bohemia: 25 million tons, 40–45% Fe.

Kosice district, Slovakia: 30 million tons, 32–38% Fe.

Potential reserves of lower grade siliceous ores or high mining cost ores in Czechoslovakia amount to at least 100 million tons.

Ref.: C. W. Wright, 1939, p. 30; Ir. Coal Tr. Rev. 140 (3756): 321–322, 1940.

FRANCE:

Brittany and Anjou: 150 million tons, 48–52% Fe. *Normandy:* "well over" 300 million tons, 45% Fe. Potential reserves of each of these districts of N. W. France are first magnitude.

Lorraine: 4,000 million tons, 30–40% Fe, actual ore. The potential reserve is about the same size. (The extension of the Lorraine field into *Luxembourg* gives this country about 150 million tons actual ore.)

Ref.: F. Clerf, Iron ores of France: Min. and Met. 17 (360): 567–568, 1936.

Canigou district, Pyrenees: about 50 million tons, 50–55% Fe.

FINLAND:

All Finnish deposits are considered potential. Easy access to high grade Swedish ores have made production of Finland's low grade ores unnecessary.

Jussari Island, S. W. Finland: 35 million tons, 30–40% Fe.

Porkonen-Pahtavaara, northern Finland: 50 million tons, 35–47% Fe. Ref.: J. J. Sederholm, Mineral resources of Finland: Eng. Min. Jour. 113 (4): 157–162, 1922; M. Saksela, Die Erzvorkommen Finnlands: Zeit. f. Prakt. Geol. 44: 156–163, 1936.

GERMANY:

Siegerland: 75 million tons, 35% Fe. Siderite. About 100 million tons potential.

Ilsede-Peine-Salzgitter: In 1934, 170 million tons were considered actual ore while potential reserves were over a billion tons; the tenor is 30% Fe (siliceous). However, the heavily subsidized government program has brought (at least temporarily) almost the entire reserve within the actual ore category. In 1938 the production was 3 million tons with an annual production of 20 million tons planned. On removal of the subsidy the reserve would probably revert to its former status.

Bavaria-Würtemberg-Baden area: 100 million tons, 40–50% Fe actual ore. About one billion tons potential ore, 30–40% Fe.

Lahn-Dill: 95 million tons, 42% Fe actual and about 150 million tons, 40% Fe, potential.

Thuringia-Saxony: 50 million tons, 30% Fe, actual; about 100 million tons, potential.

Ref.: E. Kohl, Die Eisenerzvorrätes des Deutschen Reiches: Preuss. Geol. Landesanst. Arch. Lägerst. H. 58, 1934; P. Krusch,

(Salzgitter) Z. Prakt. Geol. 44 (5, 6): 67–81, 89–98, 1936 and (Siegerland) Glückauf 72 (14) 321–329, 1936; C. W. Wright, 1939.

AUSTRIA:

Erzberg, Styria: 200 million tons, 33–38% Fe actual. About an equal amount potential. Ref.: C. W. Wright, 1939, p. 8; F. Friedenburg, 1938, p. 137.

GREAT BRITAIN:

Eastern England Jurassic ores: 2,000 million tons, 23–35% Fe (average ca. 30%) actual ore. About the same amount potential. The districts comprising this (actual) reserve are: *Northampton,* 1,000 million tons, 32% Fe; *Lincoln,* 400 million tons, 23% Fe; *Leicester* (marlstone), 100 million tons, 25% Fe; *Oxford-Rutland,* 200 million tons, 26% Fe; *Cleveland,* 300 million tons, 28% Fe.

Carboniferous siderite ores: 1,000 million tons, 30–35% Fe, actual reserve and over 5,000 million tons potential (25–30%). These ores occur in the Stafford, South Wales, Northumberland, York-Derby, and Glasgow-Edinburgh areas. Stafford has the largest actual reserve and South Wales the largest potential reserve (the latter district has only about 25 million actual ore, however). The use of these ores has declined greatly (less than 200 thousand tons annually).

Cumberland-Lancaster district, N. W. England: 110 million tons 50% Fe, actual. Hematite.

Ref.: M. Roesler, 1921; Iron Ore, United Kingdom: Imperial Mineral Resources Bureau, 237 pp., London, 1922; H. K. Scott, Review of Iron ore mining: Ir. Coal. Tr. Rev. 132: 122–123, 1936; F. Friedenburg, 1938; C. W. Wright, 1939.

GREECE:

Total reserves amount to about 100 million tons averaging 49% Fe. The principal deposits are in the Lake Kopias district. Other small deposits are on Euboea, Skiros, and Seriphos Islands. Ref.: C. W. Wright, 1939.

HUNGARY:

Total reserves about 80 million tons, 39% Fe. Principal districts are *Rozsnyo* and *Miskolc.* Ref.: C. W. Wright, 1939.

ITALY:

Elba: 50 million tons, 50% Fe; *Cogne, Val d'Aosta:* 10 million tons, 40–65% Fe, magnetite; *Nurra, Sardinia:* 5 million tons, 46–52% Fe. Ref.: C. W. Wright, 1939; P. Ruprecht, Neues Erzvorkommen: Metall u. Erz 36 (20): 524, 1939.

NORWAY:

Sydvaranger: 200 million tons, 35% Fe actual and 300 million tons potential. Magnetite ore, concentrated to 66% Fe. The next most important producer is the *Fosdalen* mine at *Malm* with about 50 million tons, 45% Fe ore. Next in importance is the smaller *Rodsand* titaniferous-magnetite deposit at *Nesset.*

The *Dunderland* mines, once important, are no longer operated but still contain potential reserves of several hundred million tons.

The *Narvik-Lofoten-Tromso region* of *northern Norway* has potential reserves of low grade (20–30%) ore which can be put at about 150 million tons.

Ref.: M. Roesler, 1921; E. Mossberg, Magnetitgrube Fosdalen: Met. u. Erz 29 (5): 81–84, 1932; K. L. Böckman, Mining in Norway: Eng. Min. Jour. 141 (3): 41, 1940.

POLAND:

Czestochowa district: 80 million tons, 30% Fe. *Kielce-Radom district:* 60 million tons, 28% Fe. Potential reserves amount to at least 200 million tons. Ref.: C. W. Wright, 1939; Ir. Coal Tr. Rev. 140 (3756) 321–322, 1940.

PORTUGAL:

Moncorvo district, Traz os Montes: 50 million tons, 45% Fe. (Production was a negligible 285 tons in 1940.) Estimates for this district run up to five hundred million tons (v. Zwerger). Ref.: F. Friedenburg, 1938; O. Berggren, Moncorvo iron ore deposit: Ann. Bibl. Econ. Geol. III (2): 280, 1931; R. von Zwerger, Iron ore of Tras os Montes: idem, V (1): 273, 1933.

RUMANIA:

Hunyad-Banat area: 25 million tons, 40% Fe. Ref.: F. Friedenburg, 1938, p. 384.

SPAIN:

Total reserves are estimated at 800 million tons, averaging 40–50% Fe (actual) and 1,000 million tons, potential (down to 25% Fe). These figures are the result of comparison of several estimates of Spanish reserves with consideration of depletion and several more recent studies of individual deposits. In 1910 (Stockholm report) the actual reserve was estimated at 711 million tons averaging about 50% Fe. Production since then amounts to about 130 million tons (roughly one-half of this since 1920); however, lower grade ores are coming into greater use through beneficiation.

The principal iron ore area of Spain is the *Cantabrian Cordillera* (*Viscaya, Oviedo, Leon, Santander, Lugo*) adjacent to the Biscayan coast, which accounts for about half of the actual reserves. Next in importance is *Sierra Menera* (*Teruel* & *Guadalajara*) with about 100 million tons, 50% Fe, actual reserve. The *Huelva* (*Rio Tinto*) pyrite is included (40% Fe) although iron is a by-product; the actual reserve is 150 million tons with an equal amount considered potential. Lesser reserves occur along the *southern Mediterranean coast,* in *Seville, Saragossa,* and the *Pyrenees.*

Ref.: M. Roesler, 1921; O. R. Kuhn, Spain's iron ore: Eng. Min. Jour. 121 (9): 367–372, 1926; C. H. Fritzsche, Der Eisenerzbergbau von Bilbao: Glückauf 66 (36): 1229–1234, 1929; O. Berggren, Iron mining at Ojos Negros: Ann. Bibl. Econ. Geol. III (2): 279, 1931.

SWEDEN:

Kiruna-Gellivara district, northern Sweden: 1,100 million tons, av. 62% Fe, actual reserve, and about the same amount potential. (Gellivara accounts for 400 million tons; the Kirunavaara deposit is estimated to contain 1.4 million tons per meter of depth.)

Central Sweden: 150 million tons, 55–60% Fe actual and a similar figure potential (estimate includes ore and concentrate of

35% magnetite ore). *Grängesberg* is the principal district and comprises about half of the reserve.

Ref.: M. Roesler, 1921; P. Ramdohr and H. Ehrenburg, 1929, p. 82; P. Geijer, Gällivare Malmfält: Sveriges Geol. Undersök. ser. Ca., no. 22, 1930, p. 217.

SWITZERLAND:

Fricktal: 20 million tons, 25–35% Fe. Ref.: H. Fehlmann, Die Schweizerische Eisenerzeugung: 255 pp. Bern, 1932, p. 217.

U. S. S. R.:

Krivoi Rog, Ukraine: 580 million tons, 60% Fe actual. 910 million tons potential. This is Russia's best iron deposit.

Kerch, Crimea: 1,730 million tons, 40% Fe, actual. 990 million tons, 30–40% Fe, potential.

Central Russia: Tula, 100 million tons, actual, 90 million tons, potential; *Lipetzk,* 31 million tons actual, 125 million potential; *Kursk* (excluding quartzites), 337 million tons; *Kalatsch,* 550 million tons; *Chopjor,* 163 million tons; others, 138 million tons. Most of these ores run 30–40% Fe.

North Russio: Kola Peninsula, 842 million tons, 30–50% Fe; others, 223 million tons. All but 28 million tons considered potential.

Caucasus: 215 million tons actual, 100 million tons potential. Principal deposits at *Kislowodsk* and *Daschkesan.*

Urals: Magnitogorsk, 250 million tons, 50% Fe, actual, and 250 million tons, potential; *Sverdlovsk region:* 500 million tons, 35–50% Fe; *Orsk-Kalilova:* 60 million tons, 50% Fe, actual, and 340 million tons, potential; *Beloretski,* 250 million tons; *Bakal,* 100 million tons, 30–40% Fe; *Blagodat, Kusa, Perm.* Total for Urals 1165 million tons, actual, 1245 million tons, potential.

Kazakstan and *Central Asia:* estimates included in table below. *Atassui* and *Karsakpai* are the principal fields of this region.

Western Siberia: The deposits fall into two geographical divisions, the *Nowosibirsk region* and the *Krasnojarsk region.* The ores are sent to *Stalinsk* in the *Kusnetzk basin* nearby. Estimates in the table following.

Eastern Siberia: 500 million tons, about 70 million of this considered actual. Most of this reserve is in the *Bratsko-Ilimski* area. The biggest single deposit (230 million tons) is at *Rudnogorski. Northeastern Siberia* is said to have about 200 million tons potential reserve.

Far East (Malo Khingan): There are small reserves in the *Amur Valley* which are to supply the Komsomolsk steel works in that area.

The following is a table of the iron ore reserves of Soviet Russia as of January, 1938 (millions of metric tons):

Region	Actual	Potential
North Russia	28	1,037
Central Russia	580	954
Ukraine and Crimea	2,310	1,900
Caucasus	215	100
Russia in Europe. Total	3,133	3,991
Urals	1,165	1,245
Kazakstan and Central Asia	11	107
Western Siberia	110	300
Eastern and N. E. Siberia	70	635
Far East	15	80
Russia in Asia. Total	1,371	2,367
Total U. S. S. R.	4,504	6,358

In addition to the reserves listed above there are said to be 250 billion tons of ferruginous quartzites containing 25–35% Fe, 230 billion are at Kursk and 20 billion at Krivoi Rog. Of this astounding reserve, 11 billion tons are termed "economic" (this may mean, "less remotely potential").

Ref.: V. Markov, Mineral resources of the U. S. S. R.: The Min. Jour. (London) 197: 537–539, 1937; T. Edwards, The mineral deposits of the U. S. S. R.: Min. Mag. (Lond.) 58 (5): 265–279, (6): 335–343, 1938; Iron resources of Soviet Russia: Ir. Coal Tr. Rev. 142: 415–416, 1941.

YUGOSLAVIA:

Ljubya district: 30 million tons, 45–50% Fe. *Vares district:* 40 million tons, 40–60% Fe. Ref.: C. W. Wright, 1939.

ASIA.

CHINA:

In 1924 Tegengren estimated the total reserves of China at 950 million tons; about 400 million tons averaging 42% Fe were classed as actual and about 550 million tons, averaging 36% Fe, were classed as potential. T. F. Hou in 1935 revised the estimate of total reserves upward to 1,200 million tons. The reserves occur in three principal regions listed as follows (with the important deposits in each region):

Southern Manchuria (Liaoning): ***Anshan,*** 400 million tons, 36% Fe; *Kungschangling:* 268 million tons, 34% Fe; *Miaoerkou,* 200 million tons, 36% Fe; others, 15 million tons. Total: 883 million tons. About half of this may be actual reserve. (SiO_2 = 45–55%.)

Chahar province, North China: Hsuan-Lung region, 100 million tons, 50–55% Fe, about one-third of this is actual ore. *Luan-Hsien region:* 32 million tons, 30% Fe, (52% SiO_2) potential. Others, 43 million tons. Total: 175 million tons.

Lower Yangtze valley and S. E. provinces: Tayeh, 26 million tons, 60% Fe; *O-Cheng,* 10 million tons, 55% Fe; numerous other small contact deposits with a few million tons each. Total for the Yangtze valley = 112 million. In other southeastern provinces there are a number of small deposits totaling 36 million tons.

Ref.: F. R. Tegengren, Iron ores and industry of China: Mem. Geol. Surv. China ser. A, no. 2, 457 pp., 1924 (Bain, 1933, has an excellent summary of this report); C. Y. Hsieh, Geology of the iron deposits, L. Yangtze region: idem, ser. A, no. 13, 191 pp. Eng. Summ., Apr. 1935; T. F. Hou, Mining Industry Statement: Geol. Surv. China, Spec. Rept. no. 5, Dec. 1935, p. 4 of Eng. Summ. and table 77 of text.

INDIA:

Bihar and Orissa province: 2,700 million tons, 60%-and-better Fe. Less accessible and lower grade ores may exceed this large sum. Ref.: H. C. Jones, Iron ores of Bihar and Orissa: Mem. Geol. Surv. India, vol. 63, pt. 2, p. 249, 1934.

Central provinces: Drug district, 100 million tons, 65-or-higher % Fe. *Bastar State:* 610 million tons with at least 65% Fe. Ref.: M. S. Krishnan, Mineral resources of the Central Provinces: Records Geol. Surv. India, vol. 74, pt. 3, p. 414, 1939. Potential reserves are large.

Mysore State: 100 million tons, 55–65% Fe. Potential ores may be a multiple of this sum. Ref.: W. F. Smeeth, quoted in Records Geol. Surv. India, vol. 70, pp. 147–149, 1935.

FRENCH INDO-CHINA:

There are deposits along the *Fleuve Rouge* in *Tonkin* in the northeastern part of the country and also a deposit in Cambodia in the south. 56 million tons 50% Fe ore has been reported for the former. Production in 1939 was 136,000 tons and in 1940 only 33,000 tons. Ref.: Mineral Industry during 1941, vol. 50 (1942), p. 312; J. J. Hoffet, Gisement de fer . . . (Fleuve Rouge): Acad. Sci. (Paris) C. R. vol. 208: 112–114, 1939.

JAPAN:

Total reserves are about 70 million tons. Principal deposit is at *Kamaishi, Iwata,* about 30 million tons, 50% Fe. There is a large ancient beach sand deposit of titaniferous-magnetite and limonite at *Kuji Bay* (20–25% Fe); exploitation by the sponge-iron process was attempted, then abandoned (J. Neill, Min. & Met. 23 (432): 599–600, 1942). There are several other small deposits throught the country. Production in 1936 (last available figures) was 754,000 tons.

Ref.: A. Roux, L'industrie Miniére au Japon: Annales des Mines Mem. 13 ser., vol. 7: 275–322, 1935; H. F. Bain, 1933.

KOREA:

Mozan, north Korea: there is a large deposit of low grade siliceous ore here containing, according to one report, 400 million tons. This ore is similar to the Anshan ore in Manchuria and runs 30–40% Fe, although locally there are enriched portions. Ref.: The Mining Jour. (Lond.) 195 (5280); 965, 1936; T. Kato, Origin of the Mozan iron ore: Jap. J. Geol. Geog. 16: 233–238, 1939

(geology, but no estimates). In *Hoang-hai-do* there are small limonite deposits containing a few million tons of ca. 50% Fe ore.

MALAYA:

Johore is said to contain a deposit of 50 million tons, 60–65% Fe, ore. Ref.: P. Ruprecht, Met. u. Erz 36 (18): 494, 1939. Annual production of the Malay states during 1939 and 1940 was a little under two million tons, about one-half coming from *Trengganu* and about 200 thousand tons from *Kelantan* (the remainder from Johore); estimates from these two districts were not available but the reserves must amount to at least a few tens of millions of tons.

NETHERLANDS EAST INDIES:

Celebes: according to Macke there are "several billion tons" of lateritic iron ore in central Celebes. The deposits at *Larona* had previously been estimated to contain 370 million tons.

Borneo: In the southeastern part of the island there is reported 120 million tons of ore and on the nearby island of Sebuku, another 300 million tons. According to S. G. Koon in the Mineral Industry for 1940, p. 328, plans were then under way to smelt some of the Borneo ore in Batavia; available ore was said to be 170 million tons.

Ref.: H. A. Brouwer, Geology of the Netherlands East Indies: 160 pp., New York, 1925; K. Macke, Celebes und seine Lägerstatten: Neues Jahr. ref. II, p. 379, 1937.

PHILIPPINE ISLANDS:

Surigao, Mindanao: 500 million tons, av. 47% Fe. Possibly as much more. Ref.: D. F. Frasché, Origin of the Surigao iron ore: ECON. GEOL. 36 (3): p. 284, 1941.

TURKEY:

Divrige, east central Turkey: 15 million tons, 65% Fe. Numerous other small deposits are said to bring the country's total reserves to 50 million tons. Ref.: W. Gilman, Development of Turkey's mineral resources: Min. and Met. 19 (379): 318–320, 1938.

AUSTRALIA AND MELANESIA.

AUSTRALIA:

Yampi Sound, Western Australia: Koolan island, 65 million tons, 60–65% Fe; *Cockatoo island,* 13 million tons, 60–65% Fe. Estimates are for ore above sea level.

Iron Knob district, Spencer Bay, South Australia: Iron Knob (including Iron Monarch deposit), 130 million tons, 60–69% Fe, portions of this ore contain up to 30% manganese. The combined iron and manganese content rarely is lower than 64%. *Iron Baron,* 100 million tons, over–60% Fe, non-manganiferous, These estimates are for ore in hills projecting above a plain and easily accessible.

Mount Philip, Queensland: 25 million tons, 55% Fe.

Cadia, New South Wales: 35 million tons, 50–60% Fe, potential.

Tasmania: Long Plain, 20 million tons, 65% Fe; *Blythe River,* 15 million tons, 65% Fe (actual and potential).

Ref.: O. R. Kuhn, Australian iron ore: Eng. Min. Jour. 120: 931–938, 1925; F. R. Hockey, Mining ironstone at Iron Knob: Australasian Inst. Min. Met. Proc. new series no. 79: 162–213, 1930; F. Canavan and A. B. Edwards, Iron ores of Yampi Sound: idem, no. 110: 59–101, 1938.

NEW CALEDONIA:

Noumea district (southern end of the island): 20 million tons, 52% Fe. Ref.: J. Shepherd, New Caledonia . . .: Pacific Affairs, vol. 13 (4): p. 427, Dec. 1940.

SOUTH AMERICA.

ARGENTINA:

There are no deposits of commercial importance at the present time; however, a deposit at Cerro Negro in the Sierra de Famatima has been described and is said to contain 80 million tons of ore (L. R. Catalano, Iron in Argentina . . .: Ann. Bibl. Econ. Geol. XI (2): 279, 1939).

BRAZIL:

Minas Gerães: 1,500 million tons, 65% Fe: 3,500 million tons, 50–60% Fe; 10,000 million tons, 30–50 % Fe (estimates of the Brazilian department of mines). At least the first category can be considered actual and probably much of the second. Smaller, though still quite extensive reserves occur in States adjacent to Minas Gerães, but only those in this State are economically important at the present time.

Ref.: E. Texeira, Iron ore resources of Brazil: Eng. Min. Jour. 124 (19): 730–735, 1927; C. W. Wright, Mineral resources, production, and trade of Brazil: Foreign Minerals Quart. 4 (1), 1941 (written with the collaboration of the Brazilian Dept. of Mines); A. Malozemoff, Brazil's Iron Ore: Eng. Min. Jour. 143 (12): 55–59, 1942, and idem. 144 (1): 56–59, 1943.

CHILE:

El Tofo, Coquimbo: about 20 million tons proved ore, 60–65% Fe (this figure is the result of an estimate published in 1928 minus production since and does not allow for newly developed ore). This mine accounts for most of Chile's production.

El Algarrobo, Atacama: 100 million tons, 60–65% Fe.

Ref.: Oscar Peña i Lillo, Monografia sobre el mineral de fierro de "El Tofo": Boletin Minero (Chile), Añ 44, vol. 40 (347): 121–138, 1928; Oscar Peña i Lillo, Monografia sobre el mineral de fierro de "El Algarrobo": idem, Añ 44, vol. 40 (351): 377–385, 1928.

COLOMBIA:

La Caldera, Boyocá: 35 million tons, 55% Fe. Once worked on a small scale but now inactive. Ref.: H. F. Collett, Eng. Min. Jour. 122: p. 304, 1926.

PERU:

Marcona: 100 million tons, 60% Fe. *Huacravilca, Junin:* 35 million tons, 60% Fe. *Tambo Grande, Piura:* 2 million tons, 35–50% Fe. Ref. C. W. Wright, Mineral resources, production and trade of Peru: Foreign Minerals Quart. 3 (1), 1940.

VENEZUELA:

Sierra de Imataca: Over 1,000 million tons, 45% Fe (the Pao deposit in this district, now being worked, has 60 million tons, 65% Fe). Ref.: G. Zuloaga and M. Tello B, Exploracion preliminar de la Sierra Imataca: Proc. Eighth American Scientific Congress, Washington D. C., pp. 717–735, 1942; also idem, pp. 685–686.

AFRICA.

ALGERIA–TUNISIA:

Algeria has a reserve of about 160 million tons and *Tunisia,* about 30 million tons. The ores run 50–60% Fe. The principal deposits of Algeria are *Ouenza, Beni-saf, Zaccar,* and *Rouina;* in addition there are over a dozen other small deposits strung out along or adjacent to the Mediterranean coast.

The important deposits of Tunisia are *Djerissa, Douaria, Slata,* and *Tamera.*

Ref.: G. Betier, Les Resources minerales de la France d'outremer, pt. II.: Bur. d'Etudes Geol. et Min. Coloniales, pp. 1–74, 1934.

FRENCH MOROCCO:

French Morocco has potential reserves of 60 million tons, 50 million of which are in the *Khenifra deposit.* Ref.: G. Betier, op. cit.

SPANISH MOROCCO:

Riff mines, near Melilla: 30 million tons, 50–60% Fe. Ref.: G. Betier, op. cit.; A. Heim, Iron ores of Minas del Rif: ECON. GEOL. 29: 294–300, 1934.

FRENCH GUINEA:

Conakry, Kaloum Peninsula: 2,500 million tons, 47–48% Fe, potential. Ref.: R. de la Bouglise, Gisements de fer de Conakry:

La Chronique des Mines Coloniales (Bureau d'Etude Geol. et Min. Col.), an. 5, no. 49: 116–120, 1936.

RHODESIA:

There are tremendous potential reserves of low-grade siliceous ore in both Northern and Southern Rhodesia; very little is known about them and prospects for their use appear quite remote. In Northern Rhodesia near Lake Bangweulu there is said to be about six billion tons of low grade (25%) lateritic ore. In Southern Rhodesia there are very extensive quantities of "banded ironstone" formation similar to the taconites of the Lake Superior region.

At *Que Que* in the *Quelo district* there is a small deposit of high grade (60%) hematite containing about 7 million tons which is being considered for local use. Ref.: A. M. Macregor, Geol. Surv. S. Rhodesia Bull. 31, 1937.

SIERRA LEONE:

Marampa: at this deposit located about 50 miles from the coast, there are 12 million tons of hard ore plus "much" soft ore; the tenor is 57–58% Fe. Production is about 900,000 tons a year. Farther inland (120 miles from the coast) at Tonkolili there is a large reserve of high grade (50–65%) ore which is reported to outcrop in a belt averaging 1,000 ft. wide and extending for 12 to 15 miles.

Ref.: K. Fowler-Lunn, Hematite iron ores of Sierra Leone: ECON. GEOL. 38: 59–67, 1933; Iron ore in Sierra Leone: Ir. Coal Tr. Rev. 134: p. 888, 1937.

UNION OF SOUTH AFRICA:

Postmasburg area, West Griqualand: 50 million tons, 60% Fe.

Rustenburg area, Transvaal: 50 million tons, 60% Fe. This deposit supplies ore for the Iscor works in Pretoria.

In addition to these high grade ores there are an estimated 5,900 million tons of medium grade (40–60%) ore most of which is in *Transvaal.* This figure does not include the titaniferous-magnetites of the Bushveldt complex (central Transvaal) and of the

gabbro masses in southeastern Transvaal and Zululand which are conservatively estimated at 2,000 million tons. All of the titaniferous ore and perhaps most of the medium-grade ore must still be considered protential.

Ref.: P. A. Wagner, The iron deposits of the Union of South Africa: Mem. Geol. Surv. S. Africa 26, 1928.

Togo:

Banjeli: 20 million tons, 50% Fe, potential. Ref.: F. Friedenburg, Neues. Jahrb. Ref. II, p. 768, 1938.

GENERAL REFERENCES.

1910 Committee of the 11th Int. Geol. Cong. Stockholm: The Iron Ore Resources of the World. 2 vol. Stockholm.

1921 Roesler, Max: The iron-ore Resources of Europe. U. S. Geol. Surv. Bull. 706. 150 pp.

1922 Imperial Mineral Resources Bureau, London: Iron Ore—A Summary of World Supplies. 8 vol. London.

1926 Kuhn, Olin R.: World's iron-ore resources. Eng. Min. Jour. 122 (3): 84–93.

1929 Ramdohr, P., and Ehrenburg, H.: Das Vorkommen des Eisens. Gmelins Handbuch der Anorganischen Chemie, Achte Auflage, pp. 60–184.

1929 Eckert, Max: Die Welt-Eisenerzkarte. Stahl u. Eisen 49: 1827–1832.

1933 Bain, H. F.: Ores and Industry in the Far East. 288 pp., New York.

1935 Hodge, E. T.: Available raw materials for a Pacific Coast iron industry. Office of Div. Eng. North Pac. Div., Corps of Eng., U. S. Army, Portland, Ore. Vol. III.

1938 Friedenburg, Ferd.: Die Bergwirtschaft der Erde. 504 pp., Stuttgart.

1939 Wright, C. W.: The iron and steel industries of Europe. U. S. Bur. Mines Econ. Pap. 19. 98 pp.

1938–1941 Foreign Minerals Quarterly, Vol. I–IV. U. S. Bur. Min.

1941 Minerals Yearbook, Review of 1940, U. S. Bur. Min.

Some of the journals consulted are: Mining and Metallurgy, Engineering and Mining Journal, Iron and Coal Trades Review, Mining Magazine, The Mining Journal (Lond.), Iron Age, Steel, Stahl und Eisen, Metall und Erz, Zeitscrift für Praktische Geologie, and ECONOMIC GEOLOGY. In addition there are government, State, territorial, departmental, provincial, etc. publications, journals of organizations and societies interested in mining and geology, mining company reports, etc.

SUMMARY.

The following is a tabular summary of data given in the bibliography:

Country	Actual reserve (Millions of tons)	Approx. content Fe. %	Potential reserve (Millions of tons)	Approx. content Fe. %
NORTH AMERICA				
Canada	100	50%	10,000	35%
Cuba	3,000	40	12,000	
Mexico	100	60	100	
Newfoundland	1,250	40	2,000	40
United States	3,800	45	67,000	35
Total No. Am.	8,250		91,100	
EUROPE				
Albania	20	50	—	
Czechoslovakia	55	40	100	
France	4,500	35	6,000	35
Finland			90	35
Germany	800	32	2,000	30
Austria	200	35	200	
Great Britain	3,100	30	7,000	30
Greece	100	50	50	45
Hungary	80	40	—	
Italy	60	50	—	
Norway	300	35	1,000	30
Poland	140	30	200	25
Portugal	50	45	100	
Rumania	25	40	—	
Spain	800	45	1,000	35
Sweden	1,250	62	1,250	60
Switzerland	20	30	—	
U.S.S.R. (in Europe)	3,100	45	15,000	35
Yugoslavia	70	50	—	
Total Europe	14,670		34,000	
ASIA				
China	500	40	700	35
India	3,600	60	10,000	
French Indo-China	50	50	—	
Japan	70	40	—	
Korea	70	35	300	30
Malaya	75	55	—	
Neth. E. Indies	100		1,500	
Philippines	500	47	500	
Turkey	15	65	35	
U.S.S.R. (in Asia)	1,400	45	2,400	
Total Asia	6,340		15,700	
AUSTRALIA	400	60	moderate	
New Caledonia	20	52		
SOUTH AMERICA				
Brazil	4,000	60	11,000	40
Chile	120	60	—	
Colombia			35	55
Peru	100	60	—	
Venezuela	100	60	1,000	45
	4,320		12,000	

Country	Actual reserve (Millions of tons)	Approx. content Fe. %	Potential reserve (Millions of tons)	Approx. content Fe. %
AFRICA				
Algeria	160	50	—	
Tunisia	30	50	—	
Fr. Morocco			60	
Sp. Morocco	30	55	—	
French Guinea			2,500	45
Rhodesia			very large	25
Sierra Leone	20	55	large	55
Union of So. Afr.	1,000	55	7,000	45
Togo			20	50
	1,240		12,000	
WORLD TOTAL	35,240		164,800	

This table is a rough approximation of the present status of world iron ore reserves. In 1925, Kuhn made an estimate of about 58 billion tons for the world's actual ore reserve, but included a great deal of ore, the economic prospects of which are not much brighter now than they were at that time; also many individual estimates were too high. Friedenburg [4] in 1937 complied an estimate of 60 billion tons which also is believed to be excessive.

Western Europe is well supplied with iron ore; the eastern part of Europe (excluding Russia) is rather poor in reserves. The Soviet Union is very rich in iron and although the best ore is at Krivoi Rog, there are large supplies of good ore in the Urals. England has large reserves but the grade is low and requirements are high, necessitating considerable importation of better grade ore. The United States will face a serious situation in about ten to fifteen years as a result of the depletion of high grade Lake Superior reserves. Possible solutions are importation of high grade Brazilian ore (via a St. Lawrence waterway), use of the large low-grade reserves if cheap methods of extraction can be developed, and (a partial solution) increased use of eastern magnetites and other ores. The large Cuban and Wabana reserves are also possible sources of major quantities of ore. Although

[4] Zeit. Prakt. Geol. 45 (3) : 45.

they are nearer to the United States than Brazil, their ores are of lower grade and more difficult to smelt. Asia has large reserves in India and the Philippines but China and Japan are deficient in good ores. The per capita consumption of iron of Asia (as a whole) is still but a small fraction of that in the United States or western Europe. Australia has adequate reserves for local needs. North Africa has a moderate but important reserve of good grade ore, all of which is exported. South Africa has large reserves quite sufficient for her budding iron and steel industry; their grade and location, however, will probably preclude export in any large quantity for some time.

ACKNOWLEDGMENT.

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YALE UNIVERSITY,
NEW HAVEN, CONN.,
June, 1943.

THE HYDROTHERMAL SOLUBILITY OF SILICA.[1]

GEORGE C. KENNEDY.

ABSTRACT.

The solubility of silica glass in water has been determined through the temperature range 200° C. to 420° C. at a pressure of 300 atmospheres. Some previous investigations of solubility of silica in water, it is believed, have indicated a too great solubility as a result of failure to distinguish true solubility from colloidal dispersion. The solubility is essentially zero at temperatures below 200° C. and increases to a maximum of 0.20 part silica per 100 parts water at 360° C. Solubility falls off beyond 360° C., but is only slightly less at the critical temperature of water. Solubility in the vapor phase of water appears to be a function of the density of the vapor phase, as well as of temperature. At high pressures, as the density of the vapor phase approaches that of the liquid, its ability to act as a solvent will approach that of the liquid.

INTRODUCTION.

THE science of geology in the past has been mainly a field and laboratory science concerned, for the most part, with the study of rocks and minerals in space and time. This preoccupation with the macroscopic and microscopic relationships in space and time has in part been forced upon the science by economic considerations. However, experimental laboratory investigations are becoming more and more an integral part of the science.

The outstanding work in this direction done at the Geophysical Laboratory, Carnegie Institution of Washington, is well known to all. Most of the work carried on in that laboratory has dealt with equilibrium between solid phases, whereas much less has been done that sheds light upon the hydrothermal processes of vein formation. Problems such as the sequence of ore minerals, acid

[1] Published by permission of the Director, Geological Survey, United States Department of the Interior.

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versus alkaline solutions, and transport in liquids versus gases are among those which can be solved only to a limited extent by field and microscopal work. What has already been done shows that hope for the final answer to such problems must rest on experimental laboratory investigations.

The system selected for investigation by the author was the simple system SiO_2–H_2O. This system was chosen primarily because quartz is the dominant mineral involved in hydrothermal processes, and hence one about whose genesis we are deeply concerned. The system has the further advantage of lending itself readily to an experimental investigation in that it is simple and quartz is relatively stable under wide ranges of pressure and temperature.

The investigation reported in this paper deals with the effect of temperature upon the hydrothermal solubility of silica, as narrowly defined, that is to say, the true molecular dispersion of silica in liquid water.

PREVIOUS WORK.

Previous investigations of the solubility of silica have been carried on by C. S. Hitchen,[2] J. W. Gruner,[3] V. Lenher and H. B. Merrill,[4] E. Ingerson and G. W. Morey,[5] and by many other workers. Their experiments have dealt with solubility in both liquid and vapor phases.

The most elaborate investigation to date of the solubility of silica in liquid water has been that of C. S. Hitchen, who carried out the work while at Harvard under the tenure of a Commonwealth Fellowship. Hitchen's method and results have been recently the subject of sharp criticism. He constructed a large bomb of approximately 1365 cc. capacity, fitted with a very ingenious needle valve, which permitted samples of the liquid to be drawn from the bomb from time to time. Pure amorphous

[2] Hitchen, C. S.: Inst. Min. Met. Bull. 364: 19, 1934.

[3] Gruner, J. W.: Econ. Geol. 25: 700, 1930.

[4] Lenher, V. and Merrill, H. B.: Jour. Amer. Chem. Soc. 39; 2630, 1917.

[5] Ingerson, E. and Morey, G. W.: Abs. Am. Geophys. Union, Pt. II, p. 504, Aug. 1941.

silica, prepared by neutralizing silicon tetrafluoride, was placed in the bomb, and covered with several hundred cc. of water. The bomb was held at a desired temperature for approximately 36 hours. At the end of that time part of the liquid was drawn off through the needle valve, and analyzed for its silica content. The solubilities of silica determined by this method are shown on the accompanying graph (Fig. 2). Dr. C. Frondel[6] has pointed out that this is not a true solubility measurement, but that it is rather a measurement of the amount of silica dispersed in sol form, for no provision was made to prevent particles of silica of colloidal fineness from escaping with the solution drawn off from the bomb. In reality it would appear that Hitchen's results combine, in unknown proportions, the true solubility and the colloidal dispersion method by Frondel. Evidence that the results reported by Hitchen are erroneously very high in the low temperature range has been obtained by Frondel and by Moore and Maynard.[7] Moore and Maynard have described experiments with silica sols after long standing at room temperature in concentrations of 30 parts per million that leave the colloidal nature of their preparations beyond doubt. The solubility at 25° C. reported by Hitchen is approximately 200 parts per million. Frondel prepared a silica sol by dilution of a sol containing one-half the amount of silica reported soluble at 25° by Hitchen. This preparation was heterogeneous under the ultramicroscope. It cannot be doubted that Hitchen was dealing in part with colloidal dispersions and not solely with solubilities. In explanation of the smoothness of the curves Hitchen obtained Frondel says:

> It is suggested that Hitchen and, earlier, Gruner, have measured a peptization equilibrium that simulates a true solubility. It has been shown that a real temperature equilibrium exists between a coagulum of some hydrophilic colloids and the concentration of dispersed colloid in the liquid. The equilibrium is determined by the temperature, the particle size of the sol, and the nature and concentration of the electrolyte present. This means that the coagulum has a definite "solubility," or more correctly a peptizability, and affords a "solubility" curve similar to those where true solubility obtains.

[6] Frondel, C.: ECON. GEOL. 33: 14, 1938.

[7] Moore, E. S. and Maynard, J. E.: ECON. GEOL. 24: 391, 395, 513, 1929.

Gruner charged his bombs with rock fragments, rather than amorphous silica. The author's experiments indicate that Gruner's results are much nearer the correct solubility values than are Hitchen's.

APPARATUS.

A bomb of 155 cc. capacity, connected by means of a stainless steel capillary to a Bourdon spring pressure gauge was used in determining the solubilities reported in this paper (Fig. 1).

The bomb and capillary were constructed of Allegheny 44 steel. This steel, one of the stainless steels more resistant to corrosion, is a 15 Ni. 25 Cr. alloy which maintains a high tensile strength even at red heat. For high temperature work this alloy must be stabilized with a small percentage of titanium or columbium, as unstabilized stainless steel is very subject to corrosion at temperatures above 500° C. The bomb was made tight by means of copper washers 2 mm. thick. The 45° cone of the closure piece thrusts against the washer and deforms the washer when the head of the bomb is screwed down. A stainless steel capillary was silver-soldered to the closure piece at one end of the bomb and connected to the pressure gauge. The closure piece at the other end of the bomb was fitted with a stainless steel thermocouple well.

The bomb fit snugly inside a refractory furnace tube, on the outside of which was wound a heater of nichrome wire. The furnace tube was placed within a sheet metal shell, the annular space being filled with powdered magnesia. During a run the bomb and furnace tube were horizontal.

The furnace tube was connected through a variable transformer to a 110 volt line. A given temperature can be obtained, within a few degrees, by a particular setting of the variable transformer. However the voltage was not constant enough and the furnace not well enough insulated to dispense with an automatic temperature regulator. During the first determinations the temperature was regulated by a Wheelco proportioning controller, operated by the E.M.F. from a chromel-alumel thermocouple. The proportioning controller permitted the temperature of the furnace to vary by

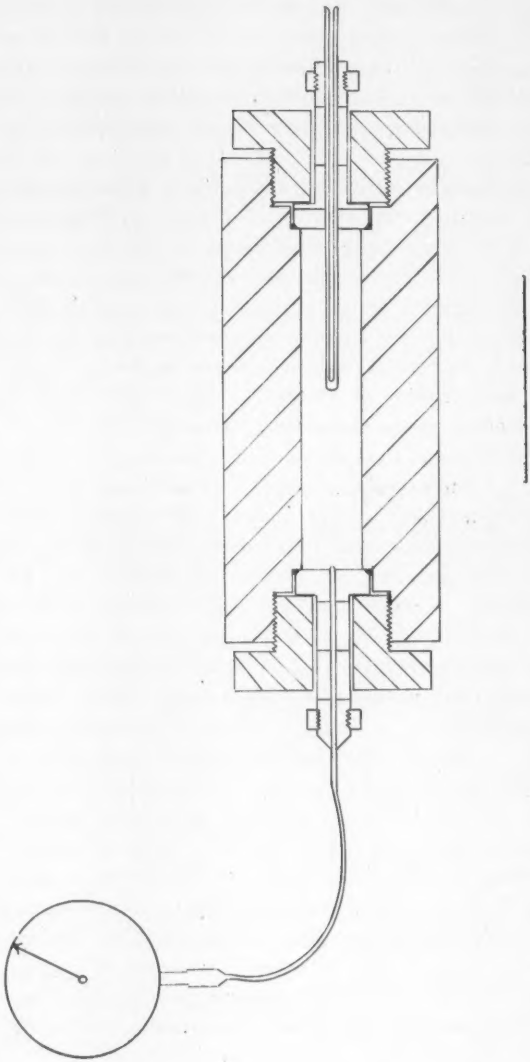


FIGURE 1.— DIAGRAM OF APPARATUS USED IN SOLUBILITY DETERMINATIONS

a degree or so. In the latter runs the temperature was regulated by a platinum resistance thermometer which formed one arm of an alternating current bridge. The output of the bridge was amplified and fed to a phase-shifting thyratron circuit. The thyratron plate current decreases as the furnace temperature rises, and conversely.

Temperature was measured by means of a chromel-alumel thermocouple inserted in the well in the bomb (see diagram of apparatus). The thermocouple wires within the well were sealed in a Pyrex glass case. The chromel-alumel couple was calibrated from time to time against the boiling point of water and the melting point of zinc. For the latter purpose a furnace of the type designed by the U. S. Bureau of Standards and employing Bureau of Standards zinc, melting at 419.5° C., was kindly loaned by Professor Oldenberg of the Harvard department of physics.

Pressures in the bomb were obtained as a result of the expansion of water as temperature increased. In the range between room tmperature and 360°, water, under vapor pressure alone, increases in specific volume from 1.00 to 1.90. The pressures, in excess of the vapor pressure, are obtained as illustrated by the following example. Suppose a solubility determination is to be made at a temperature of 350° C. and a pressure of 300 atmospheres. The specific volume of water at this temperature and pressure is 1.555. The volume of the bomb used is 155 cc., therefore approximately 100 cc. of water is placed in the bomb at the beginning of the run. As the bomb is heated the pressure increases along the vapor pressure curve and the water expands. At a femperature of about 335° C. and a vapor pressure of approximately 135 atmospheres, the water will have expanded until it occupies the entire volume of the bomb. As the bomb is heated the remaining 15° to the desired temperature the pressure increases sharply from 135 atmospheres to 300 atmospheres as the pressure departs from the vapor pressure curve and follows the water compressibility curve. Pressure-volume-temperature data for water in both the liquid and the vapor phase were taken from tables

published by Keenan and Keyes[8] and from compilations by Goranson.[9]

The calculated pressures were checked by a Bourdon type gauge. The errors in measuring pressure by means of a gauge of that type are inherently large, but were kept relatively low in the present case by frequent calibration of the gauge against the vapor pressure of water. Pressures are believed to be accurate to within 5 atmospheres.

METHOD OF MEASURING SOLUBILITY.

The solubility of silica was measured systematically between the temperatures of 200° C. and 360° C. at a pressure of 300 atmospheres (Fig. 2). Exploratory runs were made at temperatures up to 500° C. and pressures up to 1,000 atmospheres.

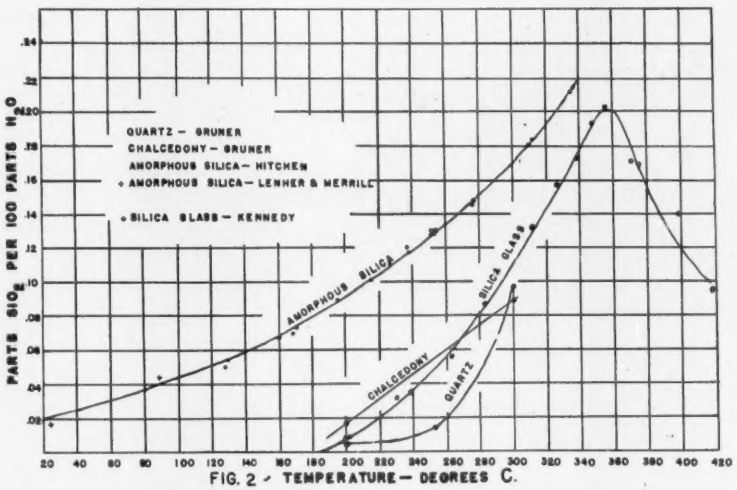


FIG. 2

[8] Keenan, J. H. and Keyes, F. G.: Thermodynamic Properties of Steam. John Wiley and Sons, New York, 1936. P. 72.

[9] Goranson, R. W.: G. S. A. Spec. Pap. 36, Handbook of Physical Constants, Sect. 14, p. 209, 1942.

Determinations of solubility were made upon threads of silica glass because of the difficulties, previously discussed, in the use of material of colloidal fineness. Pure silica glass was melted in an oxygen-gas flame and drawn out into threads several centimeters long and of about 0.5 mm. diameter. Several of these threads were sintered together into a coherent but porous bundle of glass spicules. The bundle was carefully weighed on an analytical balance and placed in the bomb together with the weight of distilled water required to give the pressure desired for that run. The bomb was then placed in the furnace and heated rapidly (about 30 minutes) to the desired temperature and held there by means of the controller. At the end of the desired time, 24 to 48 hours, the bomb was removed from the furnace and cooled in air. The charge of silica was removed from the bomb and again weighed. The loss in weight was interpreted as the amount of silica that had gone into solution. All runs were made at pressures greater than the critical pressure of water, 217 atmospheres, therefore only liquid water was present in determinations below the critical temperature. Uncertainties arising from partition of solubility between liquid and vapor phase have thus been eliminated. At temperatures above the critical temperature of water, 373° C., by definition, only a vapor was present. The relatively small amount of silica soluble in water does not appreciably affect the critical temperature.

The accuracy of this method of measuring the solubility is furthered by an inherent restraint of the tendency for silica, dissolved at higher temperatures and pressures, to redeposit on the charge as the bomb cools to permit weighing. If this happened, it would give an erroneously low figure for solubility. This restraint is imposed by the strong tendency of silica, when dissolved in water, to go over into the form of a sol. In the present experiments this invariably happened, and the mobile contents of the bomb at the end of a run consisted of a sol suspension and a few coarser flocs of silica. Under these conditions there was little or no tendency for the silica to redeposit on the remainder of the

charge or on the walls of the bomb. This was checked by microscopic examination of the residual spicules.

This general method of measuring solubilities would seem to be applicable to any substance which shows little or no tendency to redeposit back upon the original charge by crystallization from solution under the conditions of cooling.

A variation of this technique of cooling which proved satisfactory was that of opening the bomb immediately upon its removal from the furnace. Dissolved material in the water is swept out of the bomb by the escaping steam or is deposited near the escape vent from the expanding and cooling solution. The charge may be weighed and the solubility calculated as before. Under these circumstances care must be taken to unscrew the plug at such a rate that the violent outrush of superheated steam will not break and carry away part of the charge, while yet allowing all the dissolved and finely colloidal material to be driven outward.

Determinations of solubility were made for varying lengths of time. In the range of temperature between 200° C. and 250° C. equilibrium was reached within 36 hours. Above 250° C. equilibrium was attained in approximately 24 hours. Equilibrium is inferred from the fact that runs of longer duration give essentially the same result. Actually, true equilibrium did not exist as the disappearance of glass and the crystallization of one of the solid forms of silica, cristobalite, tridymite, or quartz would be expected as an indication of true solubility equilibrium. Such a conversion of glass to one of the solid forms of SiO_2 was not observed. It is believed that lack of such an expression of equilibrium does not invalidate the results, but is merely further evidence of the well known fact that such a transfer or change of state is a very reluctant one.

RESULTS.

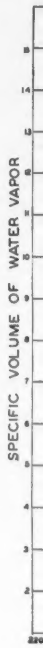
The 300 atmosphere isobaric solubility curve (Fig. 2) shows a very low solubility below 200° C. but solubility increases rapidly beyond that point. As would be expected from analogy with

slightly soluble salts solubility falls off somewhat between 360° C. and the critical temperature of water, but the peak solubility at approximately 360° C. is only slightly higher than that at 373° C.

Reconnaissance runs above the critical temperature of water have been made, but as yet no systematic data have been gathered for solubility in this gas-phase region. The indication from the reconnaissance runs strongly suggests that solubility in the gas-phase is not only a function of temperature, but is very much an inverse function of the specific volume of the water vapor. The important factor determining solubility in the vapor or gas phase is the density of that phase, i.e., the closeness of packing of molecules; the closer this packing approaches that of a liquid, the more like a liquid solvent the gas behaves.

Curves of the specific volume of liquid water up to the critical temperature, and of the gas phase beyond, have been plotted for various pressures (Fig. 3). These curves are reproduced for they are not well known to geologists. In the curve of specific volumes for 300 atmospheres pressure it will be noted that though the pressure is above the critical pressure of water, 217 atmospheres, there is a very sharp increase in the specific volume of the water immediately above the critical temperature. At this pressure marked falling off of solubility is encountered above 360° C. However at pressures of 1,000 atmospheres critical phenomenon are not reflected by any such sudden change of slope in the specific volume-temperature curve, and as no abrupt increase in specific volume takes place, no pronounced falling off of solubility is to be expected as the solution passes from liquid to gas at 373° C. The usual concept of the distinction between liquid and gas is not valid in this pressure range. For example a gas, by definition, at 380° C. and 1,000 atmospheres pressure is considerably denser, that is, it has a much closer packing of molecules than a liquid at 370° C. and 250 atmospheres pressure.

A pressure of 1,000 atmospheres corresponds to a hydrostatic rock load of approximately 11,000 feet. Geologists are in general



agreement that many if not most ores separate from the parent magma at depths of 11,000 feet or greater. At this depth and corresponding pressure the properties of a gas and a liquid are probably so nearly similar from the standpoint of their density and

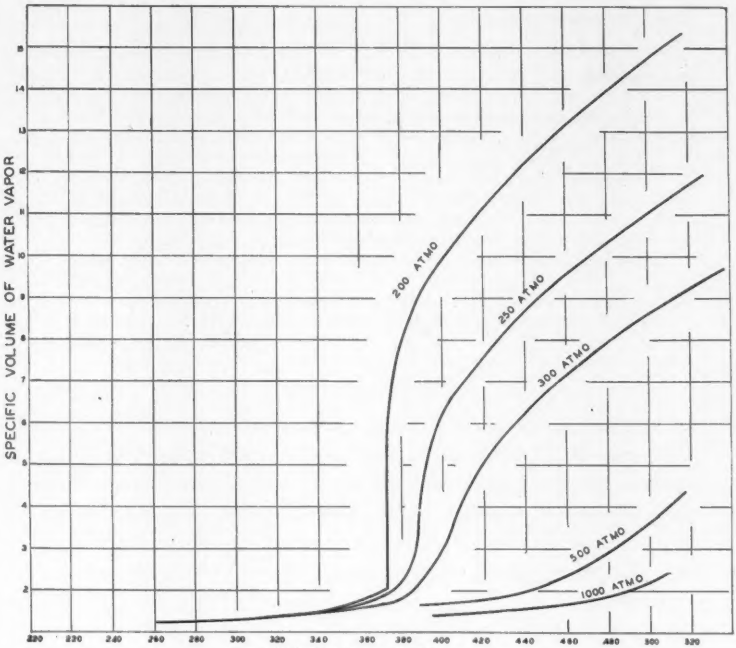


FIGURE 3

ability to act as a solvent that little is gained by advocating the existence of one phase in preference to the existence of another.

Experiments have been planned, and it is hoped will be performed in the near future, to secure precise data upon the pressure-temperature-solubility relationships above the critical temperature.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation of the aid and encouragement of the Committee on Geophysical Research at Harvard University. He especially wishes to thank Professor Francis Birch for the great amount of assistance rendered in designing and assembling the apparatus, and Professor L. C. Graton and Dr. Michael Fleischer for their critical reading of the manuscript.

U. S. GEOLOGICAL SURVEY,
WASHINGTON, D. C.,
May 3, 1943.

GEOCHEMICAL STUDIES OF THE EPITHERMAL DEPOSITS AT GOLDFIELD, NEVADA.

H. D. B. WILSON.

ABSTRACT.

Approximately fifty samples of vein material and wallrock from the ore deposits of Goldfield, Nevada, were quantitatively analyzed by means of the spectrograph to determine whether the quantitative distribution of certain elements would give some clue to the loci of mineralization. It has been established that three elements, bismuth, silver and tin, are genetically associated with gold values in the deeper veins. These elements are determinable even in very low grade vein material.

The quantitative variation of some elements in the wallrock gives hope of determining the distance of a given wallrock sample from a vein.

Vertical zoning at Goldfield is evident with respect to tin, less definite for bismuth and probably present among several of the accompanying elements.

INTRODUCTION.

QUANTITATIVE spectrochemical methods offer a rapid means of obtaining accurate chemical analyses, particularly of the rarer elements in veins and rocks. In the Goldfield district the ore is characteristically distributed in rich pockets scattered through wide silicified zones and the bonanza areas are found only by extensive development work. In such a district any guides to ore are particularly acceptable. Some clues regarding the loci of mineralization may be obtained from the quantitative distribution of the rarer elements. The problem can be attacked either by a study of the distribution of elements within a vein in the vicinity of an ore shoot or on a larger scale, by the study of the quantitative variation of particular elements in the wallrock in the region of mineralization.

ACKNOWLEDGMENTS.

I wish to thank Dr. H. J. Fraser, California Institute of Technology, for his supervision and many helpful suggestions. Mr.

H. P. Kervin, Goldfield Operators, aided the field work, obtained permission to sample certain mines and placed his intimate knowledge of the district at the writer's disposal. Dr. M. F. Hasler of the Applied Research Laboratories, Los Angeles, suggested the spectroscopic technique and gave freely of his time in discussing analytical problems.

TECHNIQUE.

The veins were channel sampled but it was later realized that other methods of sampling might have been more applicable. Individual samples weighed about two pounds to the foot and were broken at widths of five feet or less, depending on the width of the vein. The wallrock samples were five-foot channel samples taken at approximately ten-foot intervals away from the vein. The entire sample was crushed, one-quarter separated by a Jones splitter and pulverized, about one hundred grams separated and repulverized and a one-gram sample split, then ground in an agate mortar after the iron filings were removed by an electromagnet. Duplicate samples were split from each original sample.

Spectrographic analyses were made on an Applied Research Laboratories type grating spectrograph in the geological laboratories of the California Institute of Technology. A technique of silicate analysis suggested by Dr. M. F. Hasler of the Applied Research Laboratories was adapted to this problem. The analyses are quantitative but are expressed as intensity ratios rather than percentages.

An intensity ratio for any element is the ratio of the intensity of a specific line to the intensity of a specific line of another element used as an internal standard. The internal standard is an element that is present either naturally or artificially in constant amounts in every sample. Intensity ratios are directly proportional to actual percentage ratios for any two elements within restricted ranges. Lithium was used as an internal standard and each sample was diluted with 50 per cent lithium carbonate. As the spectroscopic sensitivity differs for each element an intensity ratio of 1 may represent .001 per cent actually present for one

element while the same ratio for another element may be obtained when only 0.1 per cent is present. The intensity ratios for silver to lithium were checked against silver assays and found to be directly proportional to the amount of silver present.

Duplicate analyses were made of all samples. Analyses checked within 10 per cent for all elements found useful. However where Mn and Mg are reported with ratios greater than 100, the intensity of the lines was too great to permit quantitative measurement under the conditions necessarily in use for the other elements of the sample. Some elements such as Ba, Sr, K, and Ga are present but have no spectral lines suitable for quantitative analysis under the prevailing analytical conditions.

THE ORE DEPOSITS.

The ores of Goldfield occur in "ledges" mostly in Tertiary dacite, rhyolite, and latite but also to a very limited extent in the underlying Cambrian shales. Ransome [1] has described the ledges as "irregular masses of altered and mineralized rock traversed by small, irregularly intersecting fractures, such fracturing passing in many places into thorough brecciation." The ledges are usually intensely silicified and the ore occurs in shoots and pockets within these ledges. Gangue minerals include quartz, chalcedony, alunite, kaolinite, zircon, epidote, and in some places opal. Lindgren [2] classifies the ores as gold-alunite epithermal deposits.

Figure 1 is a diagrammatic sketch of some of the principal "ledges" or veins of the Goldfield district. The greatest part of the gold and silver production of the district has come from the Consolidated ledge which contained the rich ore shoots of the Mohawk, Florence, Red Top, Jumbo Ex, and several others. The ledge has a crescent-shaped outcrop and dips toward the east. It is irregular and varies from a few feet to possibly three hundred feet in width.

The Jumbo vein, lying approximately seven hundred feet east

[1] Ransome, F. L.: Geology and ore deposits of Goldfield, Nevada. U. S. Geol. Surv. Prof. Pap. 66, 1909.

[2] Lindgren, W.: Mineral Deposits. 1933. P. 510.

of the Consolidated ledge, trends roughly north, but has many sharp angled bends. The vein ranges from about four to ten feet wide and dips almost vertically. It has been stoped along its length for about 400 feet and to a depth of from 200 to 300 feet. The vein may connect at depth with the Consolidated vein and if continued along strike would join the main Consolidated vein near the Florence shaft.

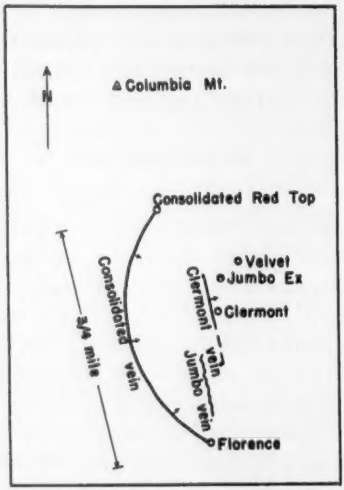


FIG. 1. Diagrammatic sketch of some of the principal veins at Goldfield, Nevada.

The Clermont vein, lying still further east, also dips to the east, but its exact dip is not known in its upper section. The Clermont vein cuts across the Jumbo Ex shaft at about the 600-foot level and may possibly join the main Consolidated vein near the 830-foot level of the Velvet shaft.

Ransome [3] has recognized three types of wallrock alteration in the district. In the first and most intense type, represented by the

[3] Ransome, F. L.: op. cit.

characteristic ledges of the district, the rocks have been changed to a porous, fine grained aggregate of quartz. In the second type the rocks are altered to a comparatively soft, light-colored mass of quartz, kaolinite, alunite, and pyrite. The boundary between these two types of alteration may be sharp or gradational. The third type is propylitic in character and is not so closely associated with ore. It has resulted in the development in the wallrock of calcite, quartz, chlorite, epidote, and pyrite. The alunitic and propylitic types are not intermixed.

Sulphide minerals common in the veins include pyrite, famatinite, and bismuthinite. Tolman and Ambrose [4] have also listed marcasite, sphalerite, wurtzite, tennantite, goldfieldite, gold-silver tellurides, and gold. A tin sulpho-salt has also been found in the Jumbo Ex mine.

LOCATION AND DESCRIPTION OF SAMPLES.

A suite of channel samples was collected from the 830-foot level of the "main" Consolidated vein in the Jumbo Ex mine. These samples were taken at ten- to twenty-foot intervals along the vein to determine the geochemical relationships of the elements within the vein. Thirty-one samples were collected from the 225-foot level of the Clermont vein around a good ore shoot. This suite included a series of wallrock samples from both the foot and hanging walls as well as vein material. A suite of samples was taken from the hanging wall (west) side of the Jumbo vein to determine changes in the dacite wall as the vein is approached on the surface. The samples were collected from an adit running perpendicular to the Jumbo vein twenty feet below the surface. These samples were at a distance of 6, 16, 25, 45, and 60 feet from the vein. This suite also contained samples of the vein material, the contact of vein and wallrock, and one of relatively fresh dacite obtained several hundred feet back in the footwall of the Consolidated ledge. This latter sample was taken to determine the difference between fresh and altered dacite. A single

[4] Tolman, C. F., and Ambrose, J. W.: The rich ores of Goldfield, Nevada. ECON. GEOL. 29: 255–279, 1934.

sample of ore was taken from the surface of a vein in the rhyolite on the east side of Columbia mountain.

The vein material from all localities is similar. It is composed of fine-grained quartz with clear coarser quartz deposited along small fractures which occasionally widen to form small vugs. The quartz carries one or two per cent of sulphides. The Clermont and Jumbo veins contain a few large grains of corroded unstrained quartz, probably original phenocrysts in the dacite but now in various stages of replacement by the later quartz. In the Jumbo vein a few straight-edged patches of fine-grained silica and pyrite suggest original phenocrysts of some ferromagnesian mineral. These veins are typical of Ransome's most intense type of alteration, that of an almost completely silicified ledge.

The wallrock of the Jumbo vein is highly altered throughout the sixty feet sampled. The wallrock of the Clermont vein is highly altered for about twenty to twenty-five feet on either side of the vein. A thin section from the Jumbo vein shows that the gradation from vein material to dacite wallrock occurs in about one millimeter. Megascopically the highly altered wallrock has a chalky white groundmass with whiter feldspar phenocrysts and dull greenish gray phenocrysts of altered ferromagnesians. In thin section the groundmass is a fine-grained mixture of alunite, quartz, kaolinite, and pyrite. The quartz phenocrysts are corroded and some pyrite has been deposited along fractures. The feldspar is completely altered to quartz, alunite and kaolinite, and the ferromagnesians are entirely altered to epidote and pyrite together with scattered quartz, kaolinite and alunite. This highly altered wallrock is a fairly advanced stage of Ransome's second, or alunitic, type of alteration.

In addition to the contact of vein and highly altered wallrock of the Clermont vein, a sharp boundary occurs between highly altered and less altered wallrock, on both hanging and footwall sides of the vein. This contact is roughly parallel to the vein-wallrock contact and in this area is about twenty-five feet from the vein. The texture of the dacite is well preserved in this less altered wallrock. Some of the labradorite appears quite fresh although most

has been partly altered to alunite. Only patches of pyrite and alunite remain as pseudomorphs of the ferromagnesians. Quartz phenocrysts are fresh and quartz also occurs in small veinlets. The groundmass is altered to quartz, alunite, kaolinite, and pyrite.

Relatively fresh dacite from several hundred feet back in the footwall of the Consolidated ledge has a gray groundmass with small quartz phenocrysts and light gray phenocrysts of fresh feldspar. This rock is still within the zone of alunitization, but it is only slightly altered when compared with other wallrock specimens. Labradorite is clear but cut by small veinlets of alunite. Many labradorite crystals show the characteristic border of glass inclusions mentioned by Ransome. Biotite is mostly altered to pyrite. Quartz phenocrysts are unaltered. The groundmass of the dacite is partly altered to quartz, alunite, kaolinite, and pyrite, but is much fresher than that observed in other specimens of altered wallrock.

DISCUSSION OF ANALYSIS OF VEIN MATERIAL.

Jumbo Ex Mine. Table I presents the intensity ratios of determinable elements in vein samples of the Jumbo Ex mine. Data of this type are used in the compilation of graphs showing the quantitative relationship of various elements in the veins.

A definite relationship exists in the Jumbo Ex between bismuth, gold, silver, and tin on the 830-foot level as shown in Figures 2, 3, and 4.

In Figure 2 the intensity ratio of bismuth is plotted against the intensity ratio of silver and tin respectively. Both figures show a straight line relationship.

In Figure 3 the intensity ratios of bismuth, silver and tin are plotted against the gold content determined by fire assay. The smooth curves of Figure 3 demonstrate the relationship between gold, silver, bismuth, and tin. If plotted logarithmically these curves become straight lines. Only one sample out of nine failed to show this relationship and even in that sample, bismuth, silver and tin were mutually related although they would not correlate with gold content.

TABLE I.

ANALYSES OF SAMPLES FROM JUMBO EX MINE, 830-FOOT LEVEL.

Element	Intensity Ratios								
	G 101	G 103	G 105	G 108	G 109	G 110	G 112	G 113	G 118
B	.39	.36	.44	.28	.61	.24	.66	.50	.44
Al	3.0	2.7	2.0	4.1	2.2	3.1	2.9	4.3	3.6
Mg	3.4	3.1	2.2	8.0	2.8	2.0	2.6	2.4	1.6
Fe	4.8	2.8	3.6	6.4	4.2	6.8	4.1	5.4	3.0
Pb	1.5	1.9	1.5	.84	1.7	1.2	1.4	1.25	.78
Bi	2.3	12.5	1.2	1.75	5.3	10.0	8.0	2.8	.76
Sn	.65	2.2	.48	.38	1.4	2.4	2.0	.75	.32
V	1.2	1.6	.90	1.0	.84	1.2	1.1	1.8	1.35
Cu	100.	100.	100.	100.	100.	100.	100.	50.	10.
Ag	1.8	16.5	.70	1.0	3.3	8.8	7.0	2.4	.40
Na	3.0	4.4	4.3	5.9	7.5	3.8	5.3	2.7	3.4
Ni	.86	.78	.70	.55	.68	.92	.56	.72	.68
Co	.97	1.0	.80	.80	1.05	.94	1.05	1.04	1.02
Mn	2.2	2.3	3.4	5.0	4.2	13.5	5.0	10.0	6.4
Cr	1.4	2.1	3.1	6.3	5.0	20.5	5.4	14.0	8.1
Ca	3.0	4.1	4.2	4.6	4.0	4.4	5.1	7.5	5.0
Zr					.29	tr	tr	tr	tr
Ti					.90				
Si	major	major	major	major	major	major	major	major	major
Ga	tr	tr	tr	tr	tr	tr	tr	tr	tr
K	wk	wk	wk	wk	wk	wk	wk	wk	wk
Ba	s	s	s	s	s	s	s	s	s
Sr	s	s	s	s	s	s	s	s	s

The distribution of bismuth, silver and tin along the 830-foot level in the Jumbo Ex is shown in Figure 4. The quantitative association of these three elements is again apparent in spite of their erratic distribution. Other elements, such as lead, present in minor amounts, show no variation like that of tin, silver, gold, and bismuth. Copper was not determined quantitatively.

The apparent relationship between chromium and manganese shown by the analyses in Table I is believed due to impurities introduced by a small amount of pulverizer steel not removable by the electromagnet.

It is possible that the quantitative relationships established in this section of the mine might be used in the search for the bonanza ore shoots characteristic of this district.

Clermont Vein. A definite relationship was found on the 830-foot level of the Jumbo Ex mine. No quantitative relationship

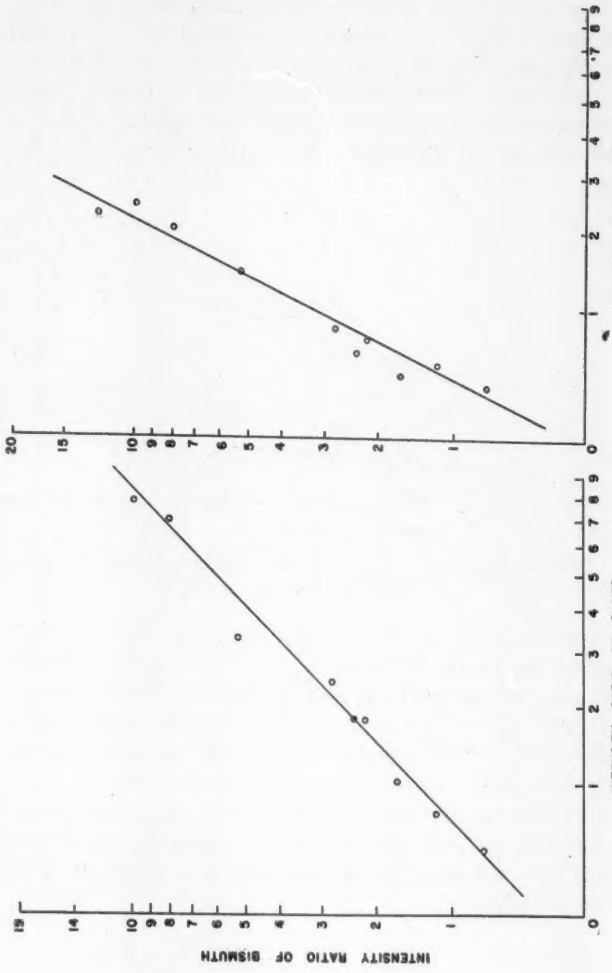


FIG. 2. Relation between bismuth and silver, and bismuth and tin on the 830-foot level of the Jumbo Ex mine. (Left) Bismuth and silver. (Right) Bismuth and tin.

between silver, gold, bismuth, and tin is evident in the Clermont vein at the 225-foot level, in the Jumbo vein near surface, or in the surface vein in rhyolite on the side of Columbia mountain. Tin and bismuth are either absent in these near surface veins or occur in very faint traces (.0005–.001 per cent) even in a sample assaying 1.60 ounces of gold whereas in deeper levels of the Jumbo Ex mine bismuth may be found in amounts up to a few tenths of one per cent.

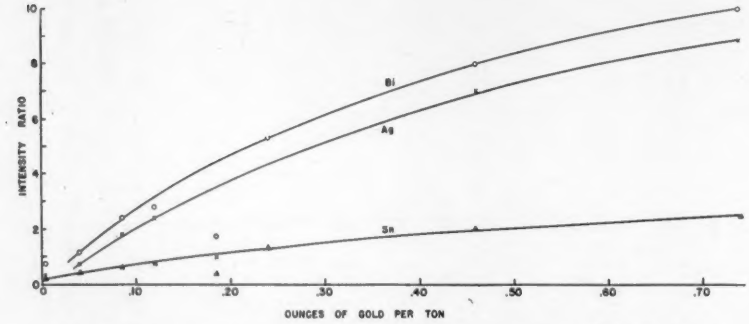


FIG. 3. Relation of bismuth, silver, and tin to gold on the 830-foot level of the Jumbo Ex mine.

The intensity ratio of silver in the Clermont vein is plotted against gold fire assays in Figure 5. No such constant relationship is shown between gold and silver as that illustrated in Figure 3 although in general higher silver values indicate higher grade gold ore. Assay results likewise show a lack of correlation between gold and silver content of these near surface veins.

Some change has apparently taken place in mineralization between the 830-foot and 225-foot levels. Bismuth and tin are more abundant and more closely associated with silver and gold in the deeper levels.

CHEMICAL CHANGES IN THE ALTERED WALLROCK.

The spectrographic method is well adapted to a study of chemical changes in wallrock alteration since data on many elements can

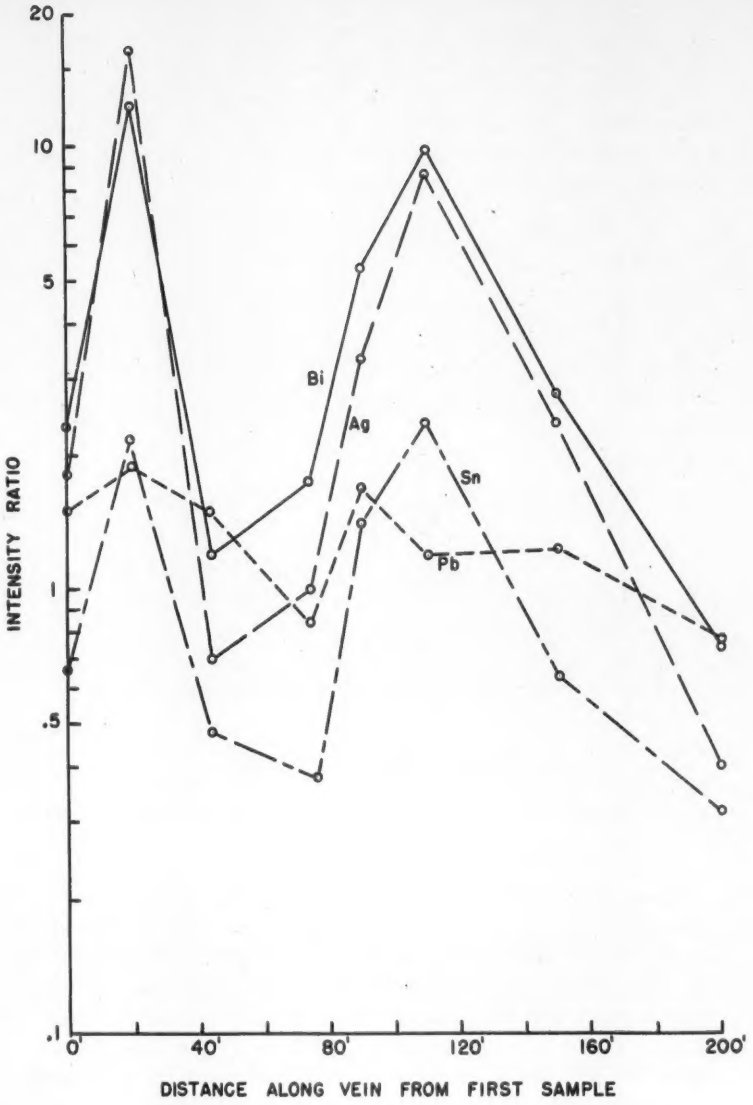


FIG. 4. Distribution of bismuth, silver, tin, and lead along the vein on the 830-foot level of the Jumbo Ex mine.

be obtained quickly and easily. The intensity ratios of certain elements are plotted against the distance of the sample from the vein in Figures 6–8 inclusive. In the following discussion, these elements are grouped according to their behavior in wallrock alteration. The relative abundance of some of the elements is indicated by approximate percentages.

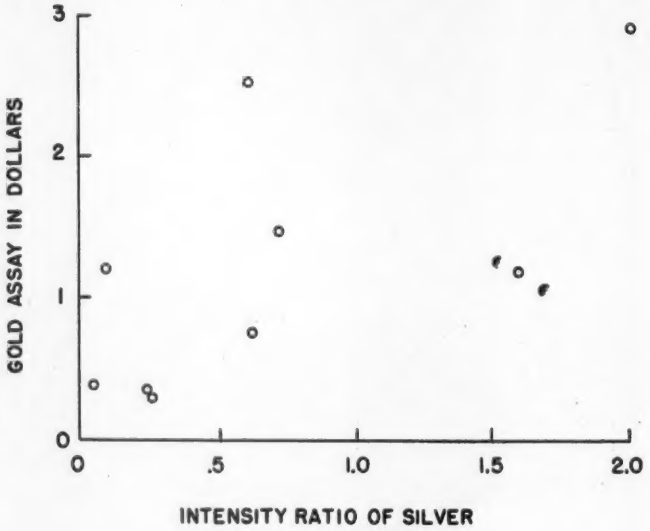


FIG. 5. Relation of silver to gold on the 225-foot level of the Clermont mine.

Elements that show little or no change during wallrock alteration include aluminium, titanium, and vanadium. The aluminium content of Goldfield samples varies from one to ten per cent with the exception of one sample from the highly silicified ledge of the Jumbo vein which contained not more than 0.1 per cent. Fresh dacite contains as much aluminium as dacite in areas of intense alunitization. The average amount of aluminium in the ledge

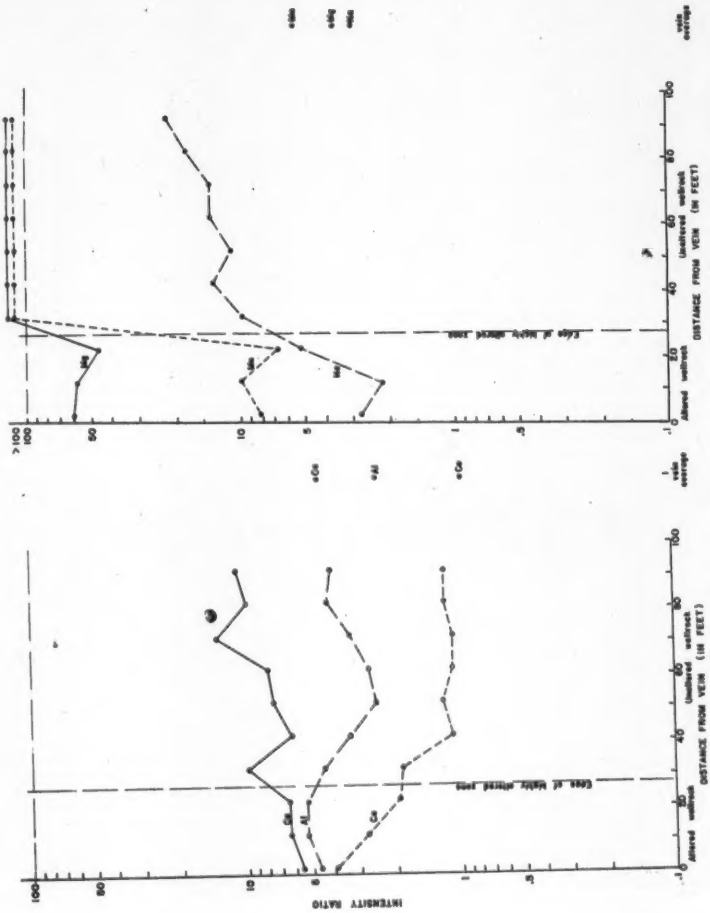


FIG. 6. Distribution of elements in the footwall of the Clermont vein on the 225-foot level. (Left) Distribution of calcium, aluminium, and cobalt. (Right) Distribution of magnesium, manganese, and sodium.

material of the Jumbo Ex and Clermont veins is somewhat lower than in the wallrock (Figure 6), but this leaching is not marked except in the Jumbo ledge where aluminum is extremely low. Titanium occurs in about equal amounts and with little variation in both veins and wallrock. The veins contain less vanadium than the wallrock but no significant variation could be found.

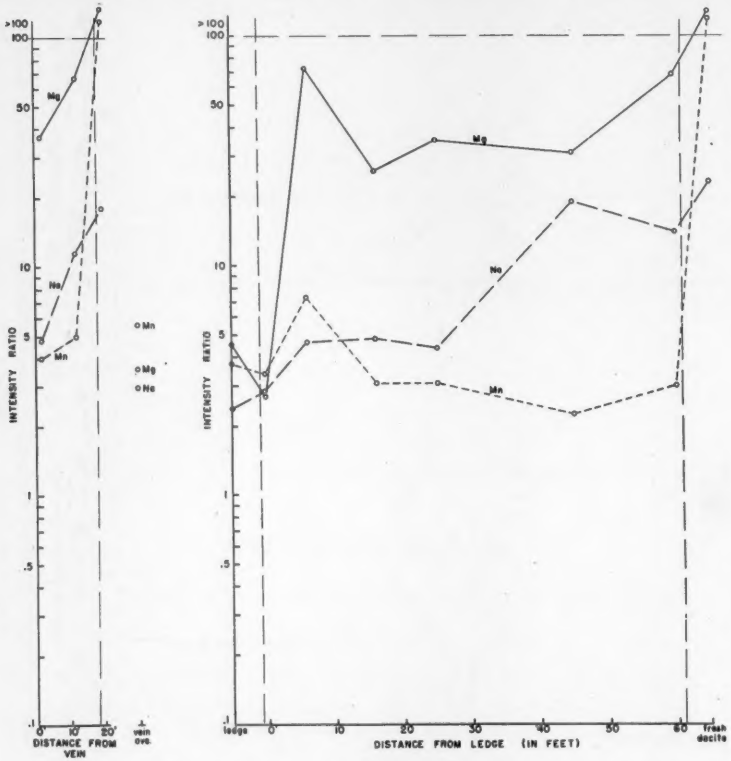


FIG. 7. (Left) Distribution of magnesium, manganese, and sodium in the hanging wall of the Clermont vein on the 225-foot level. (Right) Distribution of magnesium, manganese, and sodium in the wallrock of the Jumbo vein near surface.

Magnesium and manganese are strongly leached from the wallrock. The magnesium content shows two distinct and very sharp breaks; the change takes place within a few inches. The first break is between ledge material and highly altered wallrock, and the second is between highly altered and less altered wallrock. In the ledges the intensity ratio of magnesium varies from 1.6 to 8.0;

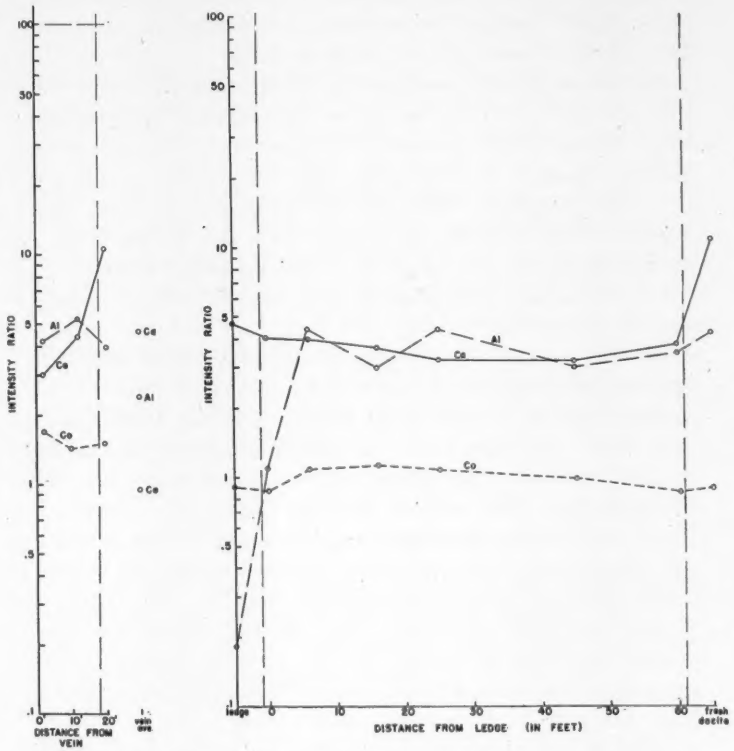


FIG. 8. (Left) Distribution of aluminium, calcium, and cobalt in the hanging wall of the Clermont vein on the 225-foot level. (Right) Distribution of aluminium, calcium, and cobalt in the wallrock of the Jumbo vein near surface.

in the highly altered wallrock from 26 to 72; and in the less altered wallrock and fresh dacite it is always greater than 100. The absolute percentage of magnesium ranges from 0.1 per cent in one of the vein samples to several per cent in the fresh dacite. The wave-like leaching of magnesium is illustrated in Figures 6 and 7 which show the sudden increase in magnesium as the contact of highly altered and less altered wallrocks is passed in the Clermont vein. Figure 7 shows the magnesium content of the ledge material, highly altered wallrock, and fresh dacite.

Manganese behaves very similarly to magnesium during alteration. It is strongly leached in the highly altered wallrock and ledge material (Figures 6 and 7), then suddenly increases as the boundary between intensely altered wallrock and altered wallrock is passed. Impurities introduced by the pulverizer plates were negligible in making this observation since they formed such a small proportion of the manganese in the less altered wallrock.

Elements showing a gradual leaching from the wallrock include sodium and possibly calcium. Vein material contains approximately the same amount of sodium as the highly altered wallrock a few feet from the vein. In the wallrock however Figures 6 and 7 suggest a gradual decrease in the amount of sodium as the vein is approached. No abrupt rise in sodium content occurs at the boundary between highly altered and less altered wallrock in the Clermont vein. The wallrock from the Jumbo vein (Figure 7) was all highly altered, but unlike magnesium and manganese which were leached over the whole distance sampled, sodium had reached a nearly constant value about forty feet from the vein. Samples farther than forty feet from the vein had almost the same amount of sodium as the fresh dacite. Calcium, although showing a definite decrease with increasing alteration, is not as highly leached as some other elements. It is present in almost constant amounts in both veins and highly altered wallrocks. In Figure 6 the leaching of calcium seems to be gradual with no marked increase in passing from highly altered to altered wallrock. In Figure 8 however, the increase at this boundary is more noticeable.

In the wallrock of the Jumbo vein near surface (Figure 8) calcium is constant and leached over the whole distance sampled.

Cobalt is the only element in these analyses which shows an enrichment in the wallrock as distinguished from the actual vein. Figures 6 and 8 illustrate this enrichment in the wallrock with enrichment gradually decreasing and becoming constant between thirty and forty feet from the vein. It is notable that cobalt is enriched only in the wallrock and not in the vein. Cobalt occurs in approximately equal and remarkably constant amounts in the vein, weakly altered wallrock, and fresh dacite (Figures 6 and 8).

Elements showing erratic and no significant distribution in both veins and altered wallrock include boron, gallium, nickel, and zirconium. Copper and lead are enriched in some of the vein material but have no significant distribution in the wallrock.

Important changes not discussed in detail include those of silica, water, potassium, and iron. Iron is fairly evenly distributed in the wallrock and does not seem to be leached. It is probable that during wallrock alteration it was redeposited almost in place as pyrite. Iron in the vein material has an erratic distribution. Petrographic studies show that silica, water and sulphate have been added to the wallrock during alteration. The distribution of potassium was not investigated.

SUMMARY

1. *Association of Elements in Veins.*

This investigation was started with the purpose of determining whether the quantitative distribution of some element or group of elements in the vein or surrounding wallrock might give some clue useful in determining the location of ore shoots.

While the present investigation represents only a first attempt and relatively few samples have been analyzed, the method gives hope of some success. It has been established that certain non-economic elements are associated with ore in this district and that these elements may be determined by spectrographic analysis.

In the vein of the Jumbo Ex mine bismuth and silver appear to

be the most promising associated elements. They are present in sufficient amounts to be determinable with the spectrograph even in extremely low grade ore. Moreover in similar samples the sensitivity of bismuth and silver could be increased two to four times by using silicon as the internal standard instead of diluting the samples with lithium. The lithium dilution method was used in this work to make the analytical results (intensity ratios) of the vein material comparable with those of the wallrock in which silica was not sufficiently constant to be used as an internal standard. If actual percentages were determined there would be no need of using the same method of arcing since standards would be set up for each method.

2. *Zoning.*

A change in the character of the mineralizing solutions has taken place between the 830-foot level of the Jumbo Ex mine and the 225-foot level of the Clermont mine. Silver, gold, bismuth, and tin are closely associated in the Jumbo Ex mine, but in the Clermont mine bismuth and tin are almost absent and silver shows no direct relationship to gold. Samples of the Jumbo vein near surface and a surface vein on the east side of Columbia mountain show some silver but no tin or bismuth.

3. *Wallrock Alteration.*

Analyses of the wallrock show a great diversity in the change in distribution of the constituent elements during the process of mineralization and the accompanying alteration of the adjacent rocks. Some elements, such as manganese and magnesium, show a sharp quantitative change at the contact between highly altered and altered wallrock, while others, such as sodium and sometimes calcium, completely fail to show any change within this zone.

Going from the vein into the wallrock, little change is apparent in the manganese and magnesium content of the wallrock until the contact between the highly altered wallrock and less altered wallrock is reached. At this contact the amount of manganese and magnesium suddenly increases tremendously, then shows little

additional change at a greater distance from the vein. On the other hand the leaching of sodium and sometimes calcium gradually decreases away from the vein with no marked boundary such as occurs with manganese and magnesium.

The wallrock of the Jumbo vein shows that magnesium, manganese, and calcium have been differentially leached over the entire distance investigated, but sodium is only leached for about forty feet from the vein and beyond that the highly altered wallrock contains almost the same amount of sodium as the fresh dacite.

Many other elements, such as boron, cobalt, copper, nickel, titanium, and zirconium, show no evident change due to wallrock alteration. Aluminium and vanadium show little evidence of change in the wallrock itself, but have been leached to a large degree in the highly silicified ledge of the Jumbo vein, which Ransome would consider the most extreme type of dacite alteration.

Cobalt showed an increase in the altered wallrock near the vein at the 225-foot level of the Clermont mine. The enrichment continued outward for thirty to forty feet from the vein.

Balch Graduate School of the Geological Sciences,
California Institute of Technology,
Pasadena, California,
April 29, 1943.

THE PURITY OF NATIVE GOLD AS A CRITERION IN SECONDARY ENRICHMENT.

ROBERT A. MACKAY.

ABSTRACT.

Emmons has stated that some secondary gold is of greater fineness than primary gold within the same orebody but urges caution in the use of such a criterion. This paper suggests that in certain types of orebody divergence in the purity and its relation to the particle size of gold may afford a clue to the zone of the orebody and an approximation of the degree of secondary enrichment.

Coarse gold is separated from the fine either by different degrees of crushing, or by amalgamation with the fine gold then recovered by cyanidation. The coarse, or amalgamated, fraction has a higher fineness of gold than the smaller particles. This divergence in fineness (or more accurately gold-silver ratio) is proportional to the degree of secondary enrichment.

Examples are taken from quartz bodies carrying pyrite, and chalcopyrite or galena or both. About forty small mines in Tanganyika and Nigeria are considered and some 200 shipments of bullion from twenty-seven of these mines were analyzed.

EMMONS [1] has stated, "In some deposits the purity, or fineness, of the gold may afford a means by which the primary may be distinguished from the secondary gold. . . . This criterion should be used with caution . . . for under some conditions doubtless secondary gold and silver are precipitated together." The writer had not encountered this statement while assembling data for this paper. Had he done so the investigation might not have proceeded, so authoritative can the quoted work be regarded, whereas the conclusions in this paper could not be drawn until a large number of data had been examined.

The writer does not gainsay Emmons' general conclusions, but presents facts which indicate that a much more definite relation is disclosed in certain deposits with silver subsidiary in amount to

[1] Emmons, W. H.: Enrichment of ore deposits. U. S. Geol. Surv. Bull. 625: 323.

gold. Emmons' examples [2] suggest that great caution must be exercised if the silver content is higher than the gold, or definitely dominant. It is hoped to stimulate discussion and further collection of data which will eventually permit the estimation of the degree of secondary enrichment with some confidence for gold deposits in tropical and possibly sub-tropical climates.

The forty or so mines [3] considered were quartz bodies carrying sparse to moderate quantities of pyrite and commonly some copper minerals, or galena, or both. The gold varied from 600 to 950 fine.

GENERAL PRINCIPLES.

Attention was first drawn to the subject by the following observations on the Lupa Goldfield in Tanganyika Territory:

1. If the amount of gold per ton fell off in depth, the fineness, or more accurately the gold-silver ratio, fell off sympathetically. (This is represented as a generalization in Fig. 3.)
2. The ratio of gold to silver was always higher in the gold won by amalgamation than that won from the same batch of ore by cyanidation.
3. The discrepancy between the gold-silver ratios for these two classes of mill bullion was great for secondarily enriched ore and small for primary ore.

The interpretation of these observations is that the purer, or secondary, gold is usually more easily freed and coarser, and is mostly recovered by amalgamation. The less pure primary gold is in much smaller average particle size, is less easily freed by grinding, and a high proportion of it is recovered at the cyanidation stage. Although not fully proved, it is difficult to find a better explanation, for cyanide has no preferential affinity for silver. Furthermore, no silver is known on the Lupa field in any form other than the gold-silver alloy, and therefore these two

[2] Emmons, W. H.: op. cit., pp. 324–348.

[3] For obvious reasons the properties cannot be named but are represented by letters. The list is lodged with the C. I. M., Mines Dept. Nigeria.

metals must together amalgamate with the mercury. The possibility of small particles of the primary metals having a higher silver content than large primary particles seems very unlikely, and such an explanation is inconsistent with observation 3 above.

FIELD OBSERVATIONS.

Examples on the Lupa Goldfield in Tanganyika Territory supporting the first observation are numerous.

At mine **A**, where the geology and assay plans clearly indicate enrichment, the values above the first level at 70 feet were in the order of 2 oz./ton, and the fineness of the gold (by amalgamation) was over 800, whereas at the bottom of the mine at 130 feet values were in the order of 0.5 oz./ton, and the fineness seldom exceeded 700.

At mine **B**, No. 1 orebody, values fell off drastically, becoming completely unpayable between 120 and 130 feet. The difference between amalgamation gold and cyanide gold became comparatively small at the lowest point mined (about 70 feet).

At mine **L**, in 1941 the ore was still highly payable, but not so rich at 150 feet as it had been at 40 feet. The fineness had fallen over 30 points. Secondary enrichment, as indicated by decreasing grade, is distinct here, but is small compared with many properties on the field.

From mine **U** the writer has no early figures. According to the manager grade fell off to marginal values and the mine was closed. The value of the bullion fell drastically during the five years of the mine's life, except when surface ore from nearby rubble was milled. At this highly cupreous mine enrichment was extreme; in fact no primary ore of economic grade was proved.

The grade of ore from mine **YY** fell from 1.85 oz./ton to below 0.5 oz./ton at 60 to 70 feet and the mine, too small to pay at the latter figure, was closed. The quality of the bullion was good in the earlier stages but the silver content rose to 400 in one of the last shipments. The orebody was highly cupreous and secondary enrichment was undoubted. At this mine, also at mine **U**, and to a

slightly less extent at mine **A**, the veins continue in vigor at depth, but the metal contents have drastically diminished. It would be possible to quote more cases of falling grade, though few are as extreme as the last two, and at many the ore has remained economic.

The New Saza is the only moderately large mine on the Lupa field but it cannot be used as an example because milling commenced on mixed ore from development of several bodies from surface to 300 feet; when stoping commenced it was by shrinkage from 150 feet upwards, and this ore was mixed with outcrop ore from other bodies. Further, Saza mine uses no amalgamation methods. All extraction is by sliming and cyanidation and thus no comparison is possible between the types of gold. However, the writer agrees with Gallagher[4] that secondary enrichment is not an important factor here, though he differs from Gallagher in believing that it does exist to a comparatively slight extent, too small to be of economic significance. As Gallagher admits, values near the top of some of the shoots were definitely above average. He attributes this to primary variations in grade, but if this variation is due to primary conditions there should be examples quoted of variation in the opposite direction also, and none were included in his paper.

Turning to the second observation, at the mines using both cyanidation and amalgamation, there was no unexplained exception to the rule that cyanidation gold was lower in gold-silver ratio than amalgamation gold. Figure 1 includes examples of bullion from all the mines which were operating at the time the data were collected. Other mines which operated cyanide plants subsequently showed similar results but the figures were not collected.

The advantage of plotting bullion on triangular coordinates is apparent because the gold-silver ratio can immediately be read off if a straight line is drawn from the apex through the point concerned to the base of the triangle. This is extremely useful, since

[4] Gallagher, David: A microscopic study of some ores of the Lupa Goldfield. Econ. Geol. 36: 306–323, 1941.

it is the gold-silver ratio and not the fineness (dependent as the latter is on the adventitious base content) which is related to enrichment phenomena; at the same time it is useful for other reasons to have the base content accessibly recorded. Misleading results may

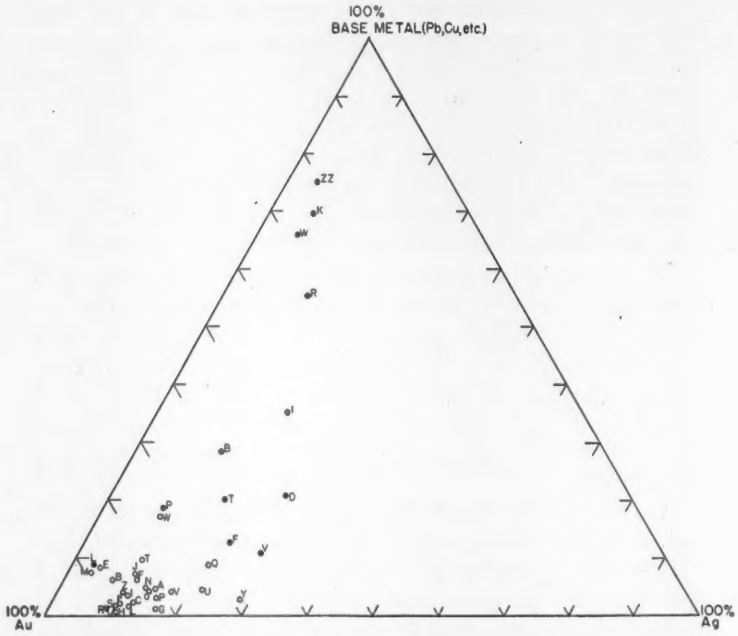


FIG. 1. Examples of Lupa Goldfield Bullion. Circles represent amalgamation plants; black points, cyanide plants. Each point represents the average of several shipments from a separate mine. Approximately 200 shipments are included from 27 mines.

be obtained in comparing bullion returns if the base content is not first eliminated. If plotted on a diagram of this kind rapid comparison may be made by pivoting a ruler about the apex, or better, by fastening a piece of cotton to a drawing pin at the apex.

At mine **P** there is no appreciable difference between the two

classes of bullion. No proper conclusion may be drawn however, because the ore supply came from two areas six miles apart, and there was a time lag of several months between the treatment of a given batch of ore by amalgamation and subsequent cyanidation. At mine **L** no comparison was possible because acid treatment of the cyanide slimes to remove copper removed much of the silver at the same time.

In considering the third observation, the percentage difference of the gold-silver ratio of bullion from amalgamation and bullion from cyanidation has been calculated for all Lupa mines using both processes. The difference is expressed as a percentage of the proportion of gold in the cyanide bullion since it is assumed to be nearer primary ore than the amalgamation bullion. The results are tabulated in Table I and show a relation between secondary enrichment (and depth) and the numerical spread between the ratios in the two types of bullion. Since this table includes mines in different kinds of country, with varying ore types, it could hardly be expected that the percentage difference would slavishly follow the figure for depth. For instance, mine **W** is much nearer highly dissected country and the ore contains more copper than mine **F**. Taking these differences into consideration the regularity of the results is surprising and, the writer submits, justifies the conclusion that the greater the proportion of gold due to secondary enrichment in an ore, the greater the percentage difference between the gold-silver ratio of the two types of bullion. The writer considers that this percentage difference between the two types of gold would show even more regular results if plotted over the course of a single mine's life, and would clearly indicate the zone in which operations were being carried out.

OBSERVATIONS ON A NEW FIELD.

The writer sought to determine whether the same principle would apply to a small new gold field in northwestern Nigeria, where milling has not yet been established. At mine **A** selected high grade ore was crushed by tributers and only recently has there been some trial milling. The gold-silver ratio of ore from this mine has

TABLE I.

Mine.	AU : AG Ratio (as a percentage).		Percentage Difference.	Approximate Depth of Ore Supply (feet).	Remarks.
	Cyanide Bullion.	Amalgamation Bullion.			
F	74.2	77.8	4.8	50	Neighboring mine L shows very slight enrichment. Flat country.
W	81.8	89.2	9.0	100–150	Deepest mine considered. Some enrichment near surface.
B	81.8	91.4	11.7	70	Enriched to 20 or 30 feet.
I	79.2	88.5	11.7	30	Depth conditions unknown.
K	79.4	89.5	12.6	40	Surface much impoverished. Richest 20–30 feet.
T	78.0	88.3	13.2	0–30	Ore supply of several small bodies.
VV	69.0	82.0	18.8	40	Enrichment was very strong. Bonanzas occurred near surface.
D	67.1	84.0	25.2	Mainly surface	Assay plan showed strong enrichment. Mine now closed down.
R	70.5	91.0	28.6	Surface to 20	Depth values unknown.
P	89.0	89.0	0	Surface and 110	Not comparative. Two sources irregularly mixed.
L	95.0	87.0	12.0 (minus)	50–100	Figures not relevant as bullion was made from slimes treated by nitric acid.

been plotted for a period of eighteen months (Fig. 2). In this diagram *A* to *B* represents the fineness of gold obtained from carefully selected ore, treated by hand crushing and panning methods. *C*, *D*, and *F* represent batches of unselected ore from several points. The ore was ground in a ball mill and the gold recovered by amalgamation. *E* represents a lower grade batch of ore which was milled. This example is of interest because it shows that the proposition of this paper does not rely only on the amalgamation-cyanidation argument. It is conclusive in this case that high grade ore (*i.e.*, selected ore containing visible gold) has a mark-

edly higher gold-silver ratio than the general run of ore. All of this ore came from within 45 feet of the surface. It was also observed that as long as selected material was handled a gradual deepening of the ore supply resulted in a slightly higher gold-silver ratio. This is attributed to the probability that the zone of maximum enrichment had not yet been passed.

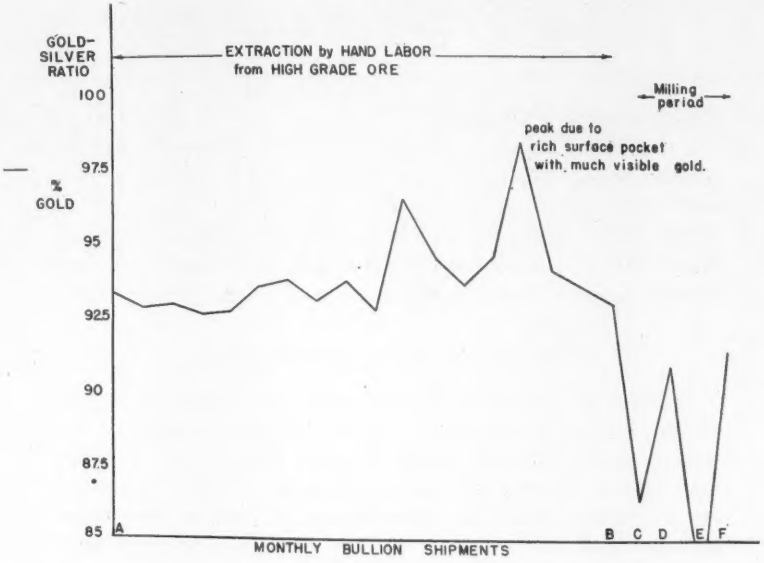


FIG. 2. Mine "A," Northern Nigeria. Gold-silver ratio in bullion.

Another small property on the same field, the only other where records were as yet obtainable, showed different values for different bodies (Table II). Unfortunately the intermediate figures for vein *A* are lacking, but assuming the maximum enrichment to have been about reached in the shallower of these two workings, the values conform in type with Figs. 2 and 3.

The implication that secondary enrichment has been operative in certain orebodies on the North West Goldfield of Nigeria and

TABLE II.

MINE B, NORTHERN NIGERIA.

Vein.	Fineness.		Gold-Silver Ratio.	Approximate Depth of Ore Supply (feet).
	Gold.	Silver.		
A	841	116	87 : 13	Surface to 20
A	826	134	85 : 15	60–76
B	791	164	83 : 17	Surface to 12
B	807	153	84 : 16	12–30
B	821	148	86 : 14	40–50

the Lupa Goldfield (Tanganyika Territory) does not infer that all the orebodies have been affected, nor that in those affected the primary ore is of no value. On the Lupa field it has been proved that some primary ore is payable. The North West Nigerian field is new and data are few; in the only two orebodies explored below 120 feet payable ore still exists and the evidence from one of these suggests that it is within, or close to, the primary zone.

SOME THEORETICAL CONSIDERATIONS.

Figure 3 is inserted as an ideal graphical illustration of the theory advanced in this paper. In this diagram variation in the fineness of primary gold within the same orebody has been disregarded (as it has been throughout the paper). Such variations, due to primary causes, are normally far less marked than those here discussed, and do not usually tend to vary in the one direction only, nor to be marked over such a small vertical distance as is commonly the case in considering gold enrichment.

Though it is not the purpose of this paper to discuss alluvial gold, nor the chemistry of gold enrichment, two relevant aspects may be briefly considered. It was noted that fineness was always much higher for the alluvial than for any reef gold, even if the alluvial gold was obtained from the immediate vicinity of the reef of origin. This is a well-known phenomenon and is due to the differential solution of silver. It is suggested that though this action may be operative within the vein, it is a subsidiary factor,

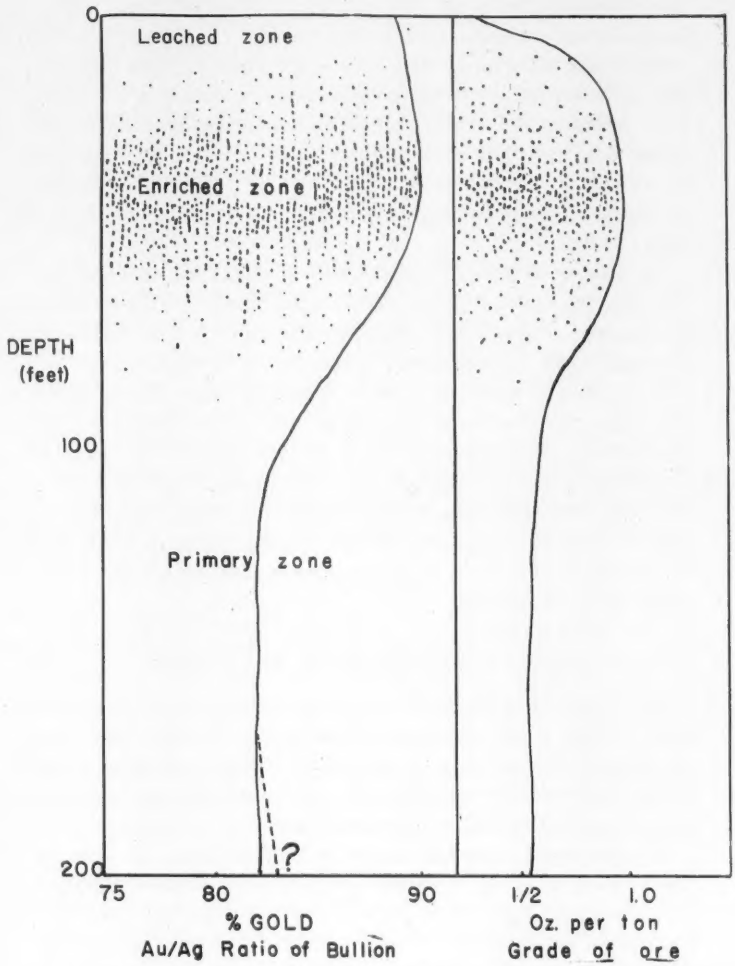


FIG. 3. Hypothetical curves for secondary enrichment of gold. Scale figures purely arbitrary.

because the change from high grade to low grade always accompanies a fall in fineness. The fate of the silver which is dissolved with the gold is also outside the scope of this paper, in that no evidence of its redeposition was encountered. Possibly it is disseminated over too large a vertical (or perhaps horizontal) range to be observed, or the primary zone of silver may not have been reached. At this point a small rise in gold may be observed at depth. This possibility is portrayed by a dotted line with a query in Fig. 3.

Secondary enrichment was marked on properties with any considerable amount of copper, even when small or negligible on neighboring comparatively non-cuperiferous orebodies with similar topography. Some chemical connection between copper and gold enrichment seems probable, a hypothesis strengthened by the occurrence of a valuable gold zone within the oxidation zone (though not at immediate surface) of copper bodies, such as those in Spain, Serbia and Cyprus where the primary gold content is very low. The precipitant effect of secondary copper sulphide on gold is mentioned by Emmons,[5] but no suggestion is made that solution is facilitated in copper-bearing bodies, which the writer thinks the facts suggest.

PRACTICAL APPLICATION OF THE METHOD.

This proposed quantitative treatment of secondary enrichment should prove a safer estimate of the degree of enrichment than methods heretofore used. A downward variation of assay values which, without other evidence, is often attributed to secondary enrichment may be due to primary changes.

Mineragraphic examination can be of assistance, but it is far from infallible. The difficulties in preparing polished surfaces from the upper zones of an orebody make this method uncertain. Moreover, because of the small quantity of metal under observation and its irregular distribution, at best the microscope gives no hope of estimating the amount of enrichment that has taken place.

[5] Emmons, W. H.: op. cit., p. 318.

Although data collected during the course of the life of a single mine rather than that collected during a shorter period from each of a fairly large number of mines would be more conclusive, two methods suggest themselves for determining whether the zone of predominantly primary gold has or has not been reached.

First, if the gold-silver ratio of the ore is plotted against depth, there should be a flattening of the curve when the zone of primary gold is approached or reached. Such a curve would be similar to the hypothetical curve of Fig. 3.

Second, the existence of enriched gold should be ascertainable, and its degree assessable, by contrasting the gold-silver ratio of the coarser and more easily released particles with that of the smaller gangue-locked particles. As suggested by the mill results discussed earlier this could be arrived at in one of two ways. The ore could be amalgamated and the residue subsequently cyanided with or without regrinding; or the gold could be extracted by amalgamation or cyanidation from coarsely ground ore (20–30 mesh) followed by extraction from the reground residue at say 150 mesh.

CONCLUSION.

It has been shown for a number of gold mines that a fall in grade is accompanied by a fall in fineness. Figures have been presented to show that coarse gold in the upper parts of an orebody has a higher gold content than the finer particles in the same ore. It is believed that this is due to secondary enrichment processes, the gold formed by secondary enrichment having less silver than the primary gold of the same orebody.

By plotting the gold-silver ratio against increasing depth, or by assaying certain separated fractions from any batch of ore, it is concluded that the degree of enrichment (at the points taken) can be estimated.

Such methods, if established, would certainly be of value, for, even between competent engineers, there is often disagreement on a new field concerning the existence and magnitude of impoverishment and enrichment.

ACKNOWLEDGMENTS.

The author wishes to thank the Nigerian Government for permission to publish; Mr. B. E. Frayling, Chief Inspector of Mines, Nigeria, and Lieut. P. Gaskell of the same department, who read and offered constructive criticism of the paper; and the Mines Department of Tanganyika Territory for many of the basic assay figures. The methods used and conclusions reached are the author's and the Governments of Tanganyika and Nigeria are in no way responsible for them.

KADUNA, NIGERIA,
April 21, 1943.

DISCUSSION AND COMMUNICATIONS

STAINING TESTS FOR DOLOMITE.

Sir: W. S. Tangier Smith in his discussion [1] of John Ridge's paper on the "Genesis of the Tri-State zinc and lead ores," discusses staining tests for dolomite. In connection with a dolomite investigation for the Province of Nova Scotia the following tests were found to be useful.

1. *Ferric Chloride.* Place a large drop of a 10 per cent (by weight) ferric chloride solution on the specimen to be tested. Leave for a minute or so. Limestone will effervesce but the appearance of the bubbles is different from that produced by hydrochloric acid. The bubbles form and seem to encrust the surface of the specimen, only occasionally rising to the surface of the drop. This is due to the lower hydrogen ion concentration in the ferric chloride solution. The reaction with dolomite is very slight. When the drop of solution is washed off, the limestone is found to be slightly stained a light brown whereas the dolomite shows no color.

2. *Titan Yellow Test.*[2] This test is not ideal for the field but can be used as a definite check on the foregoing test.

Finely powder the mineral or rock to be tested and place it in 5 c.c. of distilled water in a test tube. Add 3 c.c. of a 0.1 per cent (by weight) titan yellow solution. Shake well. Then add 2 or 3 c.c. of a 0.1 N potassium hydroxide solution and shake till there is a definite color change in the solution and then boil. Allow this solution to cool and examine the residue at the bottom of the containing vessel.

If this residue has retained its original color, magnesium is not

[1] Econ. Geol. 38: 420–422, 1943.

[2] Feigl, F.: Spot Tests. Elsevier, Amsterdam, 1937.

present, but if the residue has turned red magnesium is present. If the sample is fairly pure dolomite the red color will be distinct, whereas if it is impure the color will be less evident depending on how much dolomite is present.

G. VIBERT DOUGLAS,
A. M. KING,
J. D. MISICK.

DALHOUSIE UNIVERSITY, HALIFAX, N. S.,
November 1, 1943.

THE WORD "MICROFACIES."

Dear Sir: The recent suggestion of John S. Brown [1] that such phrases as "In thin section the rock is . . ." and "Under the microscope the mineral shows" are trite and cumbersome, is one with which I heartily agree. Furthermore, Mr. Brown's proposal [2] of *microfacies* and *microfacial* as substitute expressions merits consideration.

But before adopting these alternatives, might we not give thought to what the Germans—faced as they are with an often cumbersome phraseology—have already done. Their expression "u.d.M." is, I believe, generally accepted [3] and frequently used for "unter dem Mikroskop."

Now Americans, all the way from "A.W.O.L." and "B.P.O.E." to "W.O.W." and "W.P.B.," have long shown an inherent ability for "initializing" (if I may coin a word to make a point). To be sure, in these days of rapidly formed new agencies, both civil and military, our capacity for identifying groups of initials is sometimes strained to the utmost. Nevertheless, increased demand is bound to develop increased capacity, so would it be asking too much of petrologists and their editors and readers to employ

[1] Brown, J. S.: Suggested use of the word "microfacies." ECON. GEOL. 38: 325, 1943.

[2] Idem.

[3] Huebner, Walter: Geology and Allied Sciences: a Thesaurus and a Coordination of English and German Specific and General Terms, Part I, German-English. New York, 1939. P. 352.

and recognize the space- and time-saving expressions *u.t.m.* (for "under the microscope") and *i.t.s.* (for "in thin section"), instead of either "microfacies," "microfacially," "under the microscope" or "in thin section"? [4]

IAN CAMPBELL.

PASADENA, CALIFORNIA,
August, 1943.

PUBLICATIONS DESIRED BY NATIONAL RESEARCH COUNCIL

The following Japanese journals and publications have not been received by the principal libraries of this country, but it is possible that separates of some of the articles contained therein may have been sent to individual American geologists and paleontologists.

1. Contributions from the Institute of Geology and Paleontology, Tohoku Imperial University, Sendai, Japan. Nos. 1–32, 1921–39, inclusive. (In Japanese language—not to be confused with Science Reports of this same university.)
2. Bulletin of the Tropical Industrial Institute, Palau. Vol. 1, 1938 to date.
3. Jubilee publication in commemoration of Prof. H. Yabe—60th Birthday, Vol. 2, 1940.

Some of the above material is urgently needed at the present time. If any of these publications are available for loan or for photographing, please notify promptly the Chairman, Division of Geology and Geography, National Research Council, 2101 Constitution Ave., Washington, D. C.

[4] This manuscript was prepared before the appearance of Mr. Calkin's discussion published in ECON. GEOL. 38: 608–609, 1943.

REVIEWS*

Stratigraphy of the Eastern and Central United States. By CHARLES SCHUCHERT. Pp. xvii + 1013; Figs. 123; Charts 78; Pls. 4. John Wiley and Sons, New York, 1943. Price, $15.00.

The author of this monumental work did not live to see it in print, although it was in press at the time of his death. It is the second volume in a series dealing with the historical geology of North America. Volume I of the series, entitled "Historical Geology of the Antillean-Caribbean Region," appeared in 1935 and has become a standard reference work. Manuscript of a third volume was nearly completed before the author died, and is being edited for posthumous publication. These three volumes will present in summary form stratigraphic information on Canada and the United States east of the Cordilleran region, on Greenland, Mexico and Central America, the northern countries of South America, and the Antillean islands. An important contribution in the third volume will be the final version of Schuchert's paleogeographic maps, based on the vast amount of factual data summarized in the three volumes. These maps should do much to elucidate and make usable the material which the books document in encyclopedic form.

The present volume treats the stratigraphy of 30 States of the United States that lie west of New England and east of Montana, Wyoming, Colorado, and New Mexico. Actually considerable material is included from the bordering regions, both east and west; but only the 30 States are treated comprehensively. These States include the areas in which the standard North American section, from Cambrian upward, was in large part developed. In recognition of its outstanding place in the growth of our stratigraphic geology, New York is discussed separately and at length in the first of eight parts that follow a brief general introduction. Each of the remaining seven parts is devoted to a group of States in which the stratigraphy is related to an important structural or physiographic feature. The units on which the organization is based are the following: the Appalachian geosyncline, the Atlantic Coastal Plain, the Cincinnati anticline, the Ozark dome, the Upper Mississippi Valley, the Eastern Plains, and the old borderland Llanoria. In general,

* Books noted under *Reviews* and *Books Received* may be ordered through the Economic Geology Bookshop, M. M. Leighton, Urbana, Ill., but orders for official reports and single copies of Journals should be sent directly to their publishers.

the grouping is significant; for example, the "States Athwart the Appalachian Geosyncline" share stratigraphic characteristics related to the history of this great Paleozoic trough, and are properly discussed in sequence. Of necessity a number of States appear in more than one of the groups; thus North and South Carolina, among others, are first discussed as part of the Appalachian geosyncline, later as part of the Coastal Plain. In view of this general practise, it seems somewhat inconsistent that Alabama, including a large area of Coastal Plain, and Mississippi, which is almost wholly in this province, appear only in connection with the Appalachian geosyncline, although brief attention to the Cretaceous and Cenozoic formations of the two States follows the treatment of Paleozoic strata. It would be in the interest of completeness and logical arrangement to have correlative with Part III—"The Atlantic Coastal Plain"—another section entitled "The Gulf Coastal Plain," in which would be included the large amount of material on the Mesozoic and Cenozoic formations of Texas, which have no genetic relation to the old borderland Llanoria. Still more to the point, such a section would care for the stratigraphy of Louisiana, which, perhaps to the consternation of some readers, is omitted from the book.

Doubtless some readers will have other criticisms of the organization, especially regarding the assignment of particular States to certain groups. However these are details that have little effect on the usefulness of the book, since in the treatment of the stratigraphy the basic unit is the State, and not the group to which it is assigned. Moreover the reader soon accepts the fact that the core of the book is Paleozoic stratigraphy—the lifelong interest of the author—and that some incompleteness is to be expected in the coverage of younger formations, especially those of late Cenozoic date. Recognizing the limitations—and what human product is without them?—we accept the book as a first-class addition to the reference library in geology. The scheme used to cite publications is to give the author's name followed by the date as listed in the *Bibliography of North American Geology*. This is a commendable device, since it coordinates existing compilations and avoids useless duplication. The vast number of references represent an incredible amount of "spade work" on the part of the author. Those who knew him well realize that this systematic labor through the years was not looked on as dull drudgery. To him it was the necessary means to an objective of high value and interest—the delineation of ancient geographies. The arrangement of his source materials now serves not only to document the paleographic maps—the chief prize of his long endeavor—but also as a valuable tool for other geologists who have in view other scientific and economic goals.

CHESTER R. LONGWELL.

Bibliografia e Índice da Geologia Brasil, 1641–1940. By DOLORES IGLESIAS. Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia, Bol. 111, 1943.

This new bibliography of Brazilian geology was published as a Bulletin of the Divisão de Geologia e Mineralogia in early December, 1943. It is organized on the general plan followed by the *Bibliography of North American Geology*, published by the U. S. Geological Survey, with an alphabetical list, by authors, of more than 5,000 titles and a combined geographic and subject index.

It is planned to issue a supplementary bibliography every two years. That for 1941–1942 is now in proof and should be published at an early date.

The last comprehensive bibliography of Brazilian Geology, which appeared in 1928 as Bulletin 27 of the Serviço Geológico e Mineralógico, contained about 2,700 titles but was not indexed. The present work was compiled by Dolores Iglesias, Librarian of the Departamento Nacional da Produção Mineral. In preparing this work, she has contributed an important tool for use of those who strive to extend the frontier of geological knowledge in that great country.

Copies may be had without charge upon written application to the Biblioteca do Departamento Nacional da Produçã Mineral, Avenida Pasteur 404, Rio de Janeiro, Brazil.

W. D. JOHNSTON, JR.

Eruptive Rocks, Their Genesis Composition, and Classification, with a Chapter on Meteorites. Second Edit. By S. J. SHAND. Pp. xvi + 444; Figs. 47; Pls. 3. J. Wiley & Sons, New York, and Thos. Murby & Co., London, 1943. Price, $5.00.

Carrying on his battle to "clean up the jungle of rock names," Dr. Shand has written a second edition of his *Eruptive Rocks*, first published in 1927. The first edition was very ably reviewed by the late W. S. Bayley in volume 23 (page 811) of this journal.

In the second edition, the author has added 84 pages and several illustrations. The chapter on the relation of eruptive rocks to ore deposits has been dropped as a "subject too big to be confined to a single chapter." Except for important additions to the text where contributions to petrology since 1927 could be applied, this edition follows the arrangement of the earlier book. The addition of many references to the valuable bibliographies at the end of each chapter improves this edition over the previous. It seems unfortunate, indeed, that Dr. Shand did not include the titles of the references. The few additional pages that this

would have required would certainly not have offset the value derived from including the titles.

It must be stressed that the term eruptive rocks does not mean only effusive rocks. Using the term as first suggested by von Cotta in 1865 to imply a breaking out, Shand prefers it to the term igneous, pointing out that evidence is lacking in many rocks (granites, syenites, etc.) to consider them as "fire born." Only in lavas do we have assurance of a "fiery" origin.

The bulk of the book is devoted to the classification of eruptive rocks. In brief, the major divisions of the classification are three: (1) rocks oversaturated with silica, including granites, rhyolites, tonalites, and dacites, (2) those that are saturated: syenites, diorites, gabbros, etc., and their effusive equivalents, and (3) those that are undersaturated with silica. Class 3, in turn, is subdivided into feldspathoidal and non-feldspathoidal. The classification is logical, brief, and complete and places emphasis on the mineralogical character of the rocks classified. The classification (and the book) was designed for the petrologist, for "matter-of-fact people like physicists and chemists," and for the economic geologist. It can be of distinct value to them; in fact to anyone making use of the names of rocks.

RALPH E. DIGMAN.

BOOKS RECEIVED.

RALPH E. DIGMAN.

South African Scenery: A Textbook of Geomorphology. By L. C. KING. Pp. xxiv + 340; Figs. 307. Oliver & Boyd, Ltd., Edinburgh, 1942. Price, 25 s. net. *A very readable textbook that deals almost wholly with the geomorphology of South Africa and is primarily intended for students in this part of the world. The variety of landforms that are described, the excellent discussion of physiographic processes, and the many fine illustrations should make this book a fine reference work for any part of the world.*

The Mineral Resources of Africa. By A. W. POSTEL. Pp. 105; Figs. 17. University of Penn. Press, Phila., 1943. Price, $1.50. *Number two of the series of African Handbooks published or in preparation by the University of Penn. Press. A thorough and well-written book, this volume contains many valuable data of production and reserves, as well as illustrations including a map of mineral localities in Africa.*

The Mines Magazine: Eighth Annual Petroleum Edition. Pp. 104. Colorado School of Mines, Denver, October 1943. Price, $1.00. *This very excellent number of the Mines Alumni Association's monthly publication is devoted almost entirely to petroleum. In addition to the first thorough account of the new Elk Basin oil and gas field, the number contains articles which include: production of oxidized petroleum*

asphalt, the refining industry in war, 1942 developments in petroleum geology and geophysics, petroleum supply in the U. S., seismograph field operations, bitumen from Uinta Basin bituminous sands, oil shales in carbon minerals technology, and other important and interesting topics.

Illinois Geological Survey. Urbana, 1943.

Press Bull. 46. **Subsurface Structure and Oil Possibilities of parts of Edwards, Richland, and Wabash Counties, Illinois.** By W. H. EASTON. Pp. 12; Figs. 5.

Press Bull. 47. **Wildcat Drilling in Illinois since 1936, with Discussion of Prospects for Further Discoveries.** By C. W. CARTER. Pp. 41; Figs. 2.

Report of Investigations No. 88. **Chemical Characteristics of Illinois Crude Oils with a Discussion of their Geologic Occurrence.** By O. W. REES, P. W. HENLINE, AND A. H. BELL. Pp. 128; Figs. 6.

Report of Investigations No. 90. **High-Purity Dolomite in Illinois.** By H. B. WILLMAN. Pp. 89; Figs. 34.

Report of Investigations No. 92. **Subsurface Structure of the Base of the Kinderhook-New Albany Shale in Central and Southern Illinois.** By A. H. BELL. Pp. 13; Figs. 3; Pl. 1.

Nineteenth Biennial Report. By W. C. MORSE. Pp. 11. Mississippi Geol. Surv., University, 1943.

Mineral Occurrences in the North Hastings Area. By J. E. THOMSON. Pp. 80; Figs. 8; Pls. 10. Ontario Department of Mines, 52nd annual report. Toronto, 1943.

Barry Lake Area, Abitibi Co. and Abitibi Territory. By R. L. MILNER. Pp. 25; Figs. 3; Pls. 3. Quebec Department of Mines, Geol. Rep. 14. Quebec, 1943.

Geology (General Geology of Alberta, Rock Salt Deposit at Waterways, Geology of Alberta Soils, Relief Model of Alberta and its Geological Application, Coal Areas of Alberta). By J. A. ALLAN. Pp. 196; Pls. 45. Research Council of Alberta, Rep. No. 34, Edmonton, 1943. Price, $1.50.

The Diamond Deposits of the Gold Coast. By F. A. BANNISTER. Pp. 51; Pls. 7. Gold Coast Geol. Surv., Bull. No. 12, 1943. Price, 3 s.

Los Yacimiento de Cromo de la Provincia de Córdoba. By M. T. DERIGGI AND A. E. RIGGI. Pp. 6; Fig. 1. Tirada del Museo Argentino de Ciencias Naturales de la Revista Industria Minera No. 23, 1943.

Maps.

Oil and Gas in Middle Tennessee. By K. E. BORN. 16″ × 8″, Scale 1″ = 15 mi. Tenn. Dept. of Conservation, Division of Geol., Nashville, 1943. Price, 25 cents. *In addition to map of middle Tennessee showing oil, gas, and oil and gas localities, the sheet includes an excellent but brief history of oil and gas developments in the state, a table of data, and a columnar section.*

Chicago Areal Geologic Maps. By J. HARLEN BRETZ. 17″ × 23″, Scale 1/24,000 (2½″ = 5000′). Illinois Geol. Surv., Urbana, 1943. Price, $1.90. *Although this set consists of 24 quadrangles, 4 of the maps are withheld from distribution by direction of the War Department. The stated price is the adjusted price for 19 sheets. The maps have a contour interval of 5 feet.*

Abitibi-Timiskaming Area, Districts of Cochrane and Timiskaming, Ontario. 24″ × 40″, Scale 1/126,720 (1″ = 2 mi.). Ontario Dept. of Mines, Map No. 1934a, 2nd edit., 1943.

Eastern Extension of Fort Hope Area, Kenora District, Ontario. 20″ × 11″, Scale, 1/253,440 (1″ = 4 mi.). To accompany report, Vol. LI, Pt. 3, Ontario Dept. of Mines, 1942. Map No. 51 c.

Cunningham-Garnet Area, Sudbury District, Ontario. 14½″ × 14½″, Scale, 1/63,360 (1″ = 1 mi.). To accompany report, Vol. LI, Pt. 7, Ontario Dept. of Mines, 1942. Map No. 51 f.

Magnetic Map of Missouri, showing Anomalies of Vertical Intensity. 46″ × 41″; Scale, 1/500,000; Contour Interval, 100 gammas. Missouri Geol. Surv., 1943.

Gravimetric Map of Missouri. 46″ × 41″; Scale, 1/500,000; Contour Interval, 50 gravity units. Missouri Geol. Surv., 1943.

First Generalized Geologic Compilation Map of Colombia. By V. OPPENHEIM. 26″ × 37″; Scale, 1/2,000,000. Academia Colombiana de Ciencias Exactas, Republica de Colombia, 1943.

U. S. Geological Survey. Washington, 1943.
Water-Supply Papers.

917. **Summary of Records of Surface Waters of Missouri and St. Mary River Basins in Montana, 1881–1938.** A. H. TUTTLE AND T. R. NEWELL. Pp. 593. Price, 70 cents.

935. **Surface Water Supply of Hawaii, July 1, 1940 to June 30, 1941.** GLENN PARKER AND MAX CARSON. Pp. 140.

941. **Water Levels and Artesian Pressure in Observation Wells in the United States in 1941. Part 6, Southwestern States and Territory of Hawaii.** O. E. MEINZER, L. K. WENZEL AND OTHERS. Pp. 282; Figs. 5.

942. **Quantity of Surface Waters of the U. S., 1941.** W. D. COLLINS, C. S. HOWARD, AND S. K. LOVE. Pp. 74. Price, 15 cents.

957. **Surface Water Supply of the U. S., 1942. Part 7, Lower Mississippi River Basin.** GLENN L. PARKER AND OTHERS. Pp. 406. Price, 40 cents.

959. **Surface Water Supply of the U. S. Part 9, Colorado River Basin.** GLENN L. PARKER AND OTHERS. Pp. 347; Pl. 1. Price, 50 cents.

960. **Surface Water Supply of the U. S. Part 10, The Great Basin.** GLENN L. PARKER AND OTHERS. Pp. 123; Pl. 1.

961. **Surface Water Supply of the U. S. Part 11, Pacific Slope Basins in California.** GLENN L. PARKER AND OTHERS. Pp. 391; Pls. 2. Price, 45 cents.

SOCIETY OF ECONOMIC GEOLOGISTS

TWENTY-FOURTH ANNUAL MEETING

The Society will meet jointly with the Mining Geology Committee of the A.I.M.E. and the Industrial Minerals Division of the Institute for papers of joint interest, February 21–24, 1944, at the Waldorf-Astoria Hotel, New York City. Meetings will include three half-day sessions devoted to mining geology as applied to ore deposits, three half-day sessions devoted to economic geology as applied to industrial minerals, half a day devoted to engineering and ground water geology, and half a day devoted to economic and political aspects of geology during and after the war.

The Annual Dinner will be held on the night of Tuesday, February 22, at 7:00 o'clock, at the Columbia University Club. Members of the Society and other interested geologists attending the meetings are invited and their guests are also welcome. Reservations must be made by February 15 through the Secretary's Office. The dinner will be followed by the address of the retiring President, Mr. W. B. Heroy, and the presentation of the Penrose Medal of the Society to Dr. W. C. Mendenhall, formerly director of the United States Geological Survey.

Members planning to attend the meetings are urged to make hotel reservations as long in advance as possible as New York City hotel space is crowded. Communications should be addressed directly to the hotel selected.

JOINT MEETING SOCIETY OF ECONOMIC GEOLOGISTS AND AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS FEBRUARY 21–24, 1944.

PROGRAM.

Monday, February 21, 1944.

2:45–5:00 P.M.

The Geology of Industrial Mineral Deposits. I.

Auspices Industrial Minerals Division of A.I.M.E. and Society of Economic Geologists.

Presiding Officers—B. L. Miller and B. C. Burgess.

Each paper has been allotted 15 minutes.

1. Beryl, its sources and uses. E. H. Dawson, Mica Graphite Division, War Production Board, Washington.
2. Geological exploration for mineral deposits of the pegmatite type. H. M. Bannerman, U. S. Geol. Survey, Washington.
3. Mica in war. Wayland, Capt. R. G., U. S. Army, Hq. Army Service Forces, Washington.
4. Nonmetallic minerals speed the war. Oliver Bowles, U. S. Bureau of Mines, Washington.
5. Some lesser known properties and uses of phosphates. C. B. Durgin, Monsanto Chemical Company, Anniston, Ala.; W. A. Weyl, Pennsylvania State College, State College.
6. Four unusual pegmatite minerals from Montana. S. R. B. Cooke and E. S. Perry, Montana School of Mines, Butte.
7. Occurrence and uses of wollastonite from Willsboro, N. Y. J. G. Broughton, New York State Museum, Albany; Koert D. Burnham, St. John's Shipbuilding Co., Jacksonville, Fla.
8. New potash discoveries in Utah. B. W. Dyer, U. S. Geol. Survey, Salt Lake City.
9. Recent work on magnesium mineral resources by the Federal Geological Survey. Eugene Callaghan, U. S. Geological Survey, Washington.

Tuesday, February 22, 1944.

9:00–12:00 A.M.

The Geology of Industrial Mineral Deposits. II.

Auspices Society of Economic Geologists and Industrial Minerals Division of A.I.M.E.

Presiding Officers—H. I. Smith and H. S. Spence.

Each paper has been allotted 15 minutes.

Symposium on High-Alumina Clays.

1. Exploration of five western clay deposits. N. L. Wimmler, H. G. Iverson, S. H. Lorain, P. E. Oscarson, S. Ricker, Bureau of Mines, Western Region, Pullman, Washington.
2. High-alumina clays of Pennsylvania. R. M. Foose, Pennsylvania Geological Survey, Harrisburg.
3. Sedimentary and volcanic processes in the formation of high-alumina clays. V. T. Allen, U. S. Geol. Survey, Washington.

General Papers.

4. Mica distribution in western North Carolina pegmatites. J. C. Olson, J. M. Parker III, J. J. Page, U. S. Geol. Survey, Washington.
5. Characteristics of some New England mica-bearing pegmatites. E. N. Cameron, D. M. Larrabee, A. H. McNair, G. W. Stewart, U. S. Geol. Survey, Washington.
6. Mineralogy and petrology of the Currant Creek magnesite district, Nevada. G. T. Faust and Eugene Callaghan, U. S. Geol. Survey, Washington.
7. Geologic occurrence of rutile. C. S. Ross, U. S. Geol. Survey, Washington.
8. The Harding beryllium-tantalum-lithium pegmatites, Taos County, New Mexico. R. H. Jahns and L. A. Wright, U. S. Geol. Survey, Washington.

Tuesday, February 22, 1944.

12:00–2:00 P.M.

Council Meeting, Society of Economic Geologists, at luncheon, Parlor "D," Shelton Hotel.

W. B. Heroy, Presiding.

2:00–5:00 P.M.

Post-War Mineral Control.

Auspices War Projects Committee, Mineral Economics Committee, Mining Geology Committee and Industrial Minerals Division of A.I.M.E., and the Society of Economic Geologists.

Presiding Officers—D. H. McLaughlin and R. C. Allen.

1. Control of mineral supplies of the Axis powers to preserve peace. C. K. Leith, War Production Board, Washington.
2. Petroleum. W. B. Heroy, Office of Petroleum Administrator for War, Washington.
3. Post-war control of Axis power as regards aluminum and magnesium and their raw materials. P. D. Wilson, War Production Board, Washington.

4. The iron and steel situation. W. S. Tower, American Mine and Steel Institute, New York City.
5. Mineral control, wise or unwise? P. D. Merica, The International Nickel Company, Inc., New York, N. Y.
6. Mineral control and Asian problems. H. Foster Bain.
7. The Canadian viewpoint. G. C. Bateman, Department of Munitions and Supplies, Ottawa.

Tuesday, February 22, 1944.

7:00 P.M., Columbia University Club, 4 W. 43 St.

Annual Dinner, Society of Economic Geologists.

Address by President W. B. Heroy of the Society. Presentation of Penrose Medal of the Society of Economic Geologists to Dr. W. C. Mendenhall, formerly Director of the U. S. Geological Survey. The Medalist will be introduced by Dr. Donald H. McLaughlin and the Medal will be presented by John M. Boutwell, President-elect. Visiting geologists and their ladies are invited. Dress optional. Reservations must be made by February 15.

Wednesday, February 23, 1944.

9:00–12:00 A.M.

Ground Water and Engineering Geology.

Auspices Society of Economic Geologists, and Industrial Minerals and Petroleum Divisions and Mining Geology Committee of A.I.M.E.

Presiding Officers—C. P. Berkey and W. B. Heroy.

Each paper has been allotted 15 minutes.

Symposium: Limiting factors of perennial yield of artesian reservoirs.

1. Problems of the perennial yield of artesian aquifers. O. E. Meinzer, U. S. Geol. Survey, Washington.
2. The perennial yield of artesian water in the coastal area of Georgia and northeastern Florida. M. A. Warren and H. H. Cooper, Jr., U. S. Geol. Survey, Tallahassee, Fla.
3. Geologic factors affecting the perennial yield of artesian aquifers in three areas in Mississippi. G. F. Brown, U. S. Geol. Survey, University, Miss.
4. Quantitative studies of some artesian aquifers in Texas. W. F. Guyton, U. S. Geol. Survey, Louisville, Ky.; N. A. Rose, U. S. Geol. Survey, Houston, Tex.
5. Salt-water encroachment in limestone at Silver Bluff, Miami, Florida. R. H. Brown and G. G. Parker, U. S. Geol. Survey, Miami.

Papers on General Engineering Geology.

6. Geologic problems at limestone dam sites in the Tennessee Valley. B. C. Moneymaker, Tennessee Valley Authority, Knoxville.

7. Geology applied to military tactics. H. D. Erwin, Union Mines Development Corporation, Grand Junction, Colorado.
8. Geology and mining problems of the Conemaugh River reservoir. Shailer Philbrick, War Department, U. S. Engineer Office, Pittsburgh, Pa.

Wednesday, February 23, 1944.

9:00–12:00 A.M.

Mining of Industrial Minerals.

Auspices Industrial Minerals Division and Mining Methods Committee, A.I.M.E.

Presiding Officers—P. B. Bucky and J. R. Cudworth.

Each paper has been allotted 15 minutes.

1. Mica—mining and preparation cost; Second report. B. C. Burgess, Mining Engineer, Spruce Pine, N. C.
2. Stope filling at the Baker borax mine, California. C. G. Grim, Pacific Coast Borax Co., Boron, Calif.
3. The roofing granules industry in Pennsylvania. R. M. Foose, Pennsylvania Geological Survey, Harrisburg.
4. Block talc. J. E. Eagle, U. S. Geol. Survey, Washington.
5. Quarrying methods of the Barre, Vermont district. W. P. Mould, Rock of Ages Corporation, Barre.
6. Flow of granular materials in bins. S. M. Shallcross, Warner Company, Philadelphia.
7. The recovery of pyrite from coal mine refuse. D. R. Mitchell, The Pennsylvania State College, State College.

Wednesday, February 23, 1944.

12:15–2:00 P.M., Casino Room, Belmont Plaza Hotel

Meeting at Luncheon of Mining Geology Committee of the A.I.M.E.

The committee has cordially invited the members of the Society of Economic Geologists to attend this luncheon.

Wednesday, February 23, 1944.

2:00–5:00 P.M.

Progress in the Search for Ores.

Auspices Mining Geology Committee of A.I.M.E. and Society of Economic Geologists.

Presiding Officers—G. F. Loughlin and John M. Boutwell.

Each paper has been allotted 15 minutes.

1. Recent developments in Arizona metal deposits. E. D. Wilson, University of Arizona, Tucson.

2. Recent exploratory work by the U. S. Bureau of Mines. E. F. Fitzhugh, U. S. Bureau of Mines, Washington.
3. The iron ore situation in the Western States. E. F. Burchard and C. F. Park, Jr., U. S. Geol. Survey, Washington.
4. Adirondack and Highlands magnetite deposits. A. F. Buddington, Princeton University, Princeton, N. J.
5. Foreign work by the Geological Survey, U. S. Department of the Interior. J. V. N. Dorr 2d, U. S. Geol. Survey, Washington.
6. Some recent developments in the Canadian mineral industry. E. S. Moore, University of Toronto, Toronto, Canada.
7. Exploration for ore deposits—Viewpoint of education and training. B. S. Butler, University of Arizona, Tucson.
8. Geology in mining. Harrison Schmitt, Mining Geologist, Silver City New Mexico.
9. Knowledge of metal reserves in the western United States. Augustus Locke, Mining Geologist, Menlo Park, Calif.

Thursday, February 24, 1944.

9:00–12:00 A.M.

New Descriptions of Ore Deposits. I.

Auspices Society of Economic Geologists and Mining Geology Committee of A.I.M.E.

Presiding Officers—C. D. Hulin and Harrison Schmitt.

Each paper has been allotted 15 minutes.

1. Structural relations of the copper deposits at Matahambre, Cuba. E. N. Pennebaker, Mining Geologist, Kimberly, Nevada.
2. Mineralogy of the copper ores at the Matahambre mine, Cuba. B. K. Haffner, Bunker Hill and Sullivan Mining and Concentrating Co., Kellogg, Idaho.
3. The geology of the manganiferous iron ore deposits at Boston Hill, New Mexico. L. P. Entwistle, American Smelting and Refining Co., Magdalena, N. M.
4. Colloidal deposition of cinnabar. J. P. Pollock, Groundhog Mine, Vanadium, N. M.
5. Molybdenite deposits and pegmatites in the Preissac-La Corne area, Abitibi County, Quebec. G. W. H. Norman, Geological Survey, Ottawa, Canada.
6. Exploration of the Stillwater chromite deposits, Stillwater and Sweetgrass counties, Montana. P. T. Allsman and E. W. Newman, U. S. Bureau of Mines, Salt Lake City.
7. Investigations of mercury deposits by Bureau of Mines, U. S. Department of the Interior. McHenry Mosier, U. S. Bureau of Mines, Washington.

8. Locating pegmatites by airplane. Preliminary report. Roscoe J. Whitney, New York and New England States Council on Mineral Industries, Boston.

Thursday, February 24, 1944.

2:00–5:00 P.M.

New Descriptions of Ore Deposits. II.

Auspices Society of Economic Geologists and Mining Geology Committee of A.I.M.E.

Presiding Officers—G. M. Fowler and D. F. Hewett.

Each paper has been allotted 15 minutes.

1. The Taxco mining district, Guerrero, Mexico. A preliminary paper. G. M. Fowler, R. M. Hernon, and E. A. Stone, Consulting Engineers, Joplin, Mo.
2. Factors in the localization of mineralized districts. C. D. Hulin, University of California, Berkeley.
3. The war minerals investigations of the Geological Survey in Alaska. J. C. Reed, U. S. Geol. Survey, Washington.
4. The zinc deposits of the Groundhog Basin, Wrangell district, southeastern Alaska. H. R. Gault, U. S. Geol. Survey, Washington.
5. Iron deposits of Kansaan Peninsula, Prince of Wales Island, southeastern Alaska. L. A. Warner, U. S. Geol. Survey, Washington.
6. Magnetic exploration of the Bohemia Basin nickel-copper deposits, southeastern Alaska. M. S. Walton, Jr., U. S. Geol. Survey, Washington.
7. Geology of the quicksilver deposits of southwestern Alaska. W. M. Cady, R. E. Wallace, and E. J. Webber, U. S. Geol. Survey, Washington.

Abstracts of Papers Presented at the Twenty-Fourth Annual Meeting in Conjunction with the American Institute of Mining and Metallurgical Engineers, New York City, February 21–24, 1944.

SEDIMENTARY AND VOLCANIC PROCESSES IN THE FORMATION OF HIGH-ALUMINA CLAYS.[1]

VICTOR T. ALLEN.

Along the Pacific Coast, where volcanic materials predominate, the importance of sedimentary processes in the formation of high-alumina clays has not been fully appreciated. At Ione, Calif., Castle Rock, Wash., Whiteware, Mont., Hobart Butte and Molalla, Oreg., where the Geological Survey has been investigating clays jointly with the Bureau of Mines, U. S. Department of the Interior, sedimentary processes have been more important in the formation of high-alumina clays than have volcanic processes. Clays derived directly from volcanic materials are composed dominantly of montmorillonite; but these clays, with the exception of the beidellite-nontronite varieties, have relatively low percentages of available alumina. In contrast, clays derived by thorough leaching of various aluminous rocks under conditions favoring thorough drainage are composed dominantly of kaolinite and when sorted by sedimentary processes form high-grade deposits; furthermore, the depositional structures of these sedimentary clays have favored the derivation of gibbsite through weathering or the formation of dickite or kaolinite through hydrothermal action. Kaolinite, gibbsite, and dickite all have relatively high percentages of available alumina.

EXPLORATION ON THE STILLWATER CHROMITE DEPOSITS, STILLWATER AND SWEETGRASS COUNTIES, MONTANA.

PAUL T. ALLSMAN AND E. W. NEWMAN.

The Montana chromite deposits were the first to be explored under the Strategic Minerals Act of 1939. The Bureau of Mines conducted the exploration comprising trenching, test pitting, sampling, and diamond drilling, and the Geological Survey cooperated by mapping the geology and logging core. Investigations were started in June 1939 by a preliminary examination resulting in exploration which started August 1939 and continued until March 1943.

Over 5,000,000 tons of chromite containing in excess of 20 per cent. chromic oxide have been indicated by trenching, sampling, and core drilling. As a result of this exploration, the Benbow and Mouat-Sampson mines have been developed and fully equipped for mining and milling 500 tons and 2,000 tons daily, respectively.

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GEOLOGICAL EXPLORATION FOR MINERAL DEPOSITS OF THE PEGMATITE TYPE.[1]

H. M. BANNERMAN.

Prompted by the urgent wartime need for such mineral commodities as mica, spodumene, beryllium, tantalum, and others of pegmatitic association, the Geological Survey has been conducting a fairly extensive study of pegmatite deposits in various parts of the country. In this work the Survey has been cooperating closely with other governmental agencies in the mineral field. Two phases of the study have been emphasized, namely, reconnaissance of the more promising pegmatite-bearing areas and detailed geological mapping of individual deposits and mines. The cardinal results of these investigations will be discussed.

OCCURRENCE AND USES OF WOLLASTONITE FROM WILLSBORO, N. Y.

JOHN G. BROUGHTON AND KOERT D. BURNHAM.

Wollastonite occurs in commercial quantities in Essex county, New York, as part of a series of Grenville sediments which have been contact metamorphosed by anorthosite. Associated with it are two varieties of andradite garnet (rothoffite and colophonite) and green diopside. The presence of a high-iron garnet, diopside-hedenbergite reaction borders and associated recrystallization of the wollastonite suggests action by iron-rich post-pneumatolytic solutions.

Open-cut mining has been carried on since 1938 with an average annual production of about 100 tons. An estimated reserve of 500,000 tons is based on surface exposures alone.

The only current use is as a welding flux, both for coating metallic electrodes and as a powder in flux-shielded metallic arc welding. In the latter case, the wollastonite ore is crushed but not separated, heated to 1,200° to drive off CO_2 and ground to 80–10 mesh.

Other possible uses, dependent on the lath-like shape of cleavage particle, are as mineral filler and paint pigment diluent. It is suggested that a mineral wool of superior quality could be manufactured from the wollastonite and a nearby deposit of canaanite diopside.

GEOLOGIC FACTORS AFFECTING THE PERENNIAL YIELD OF ARTESIAN AQUIFERS IN THREE AREAS IN MISSISSIPPI.

GLENN F. BROWN.

Pumping tests furnished data for calculation of coefficients of storage and transmissibility at three army camps in Mississippi but water-level declines depend also on correct analysis of the geology of Tertiary sediments involved.

The water supply for Camp McCain comes from an upper sand of basal Claiborne age and a lower sand of middle Wilcox age. The productive basal Claiborne sand has a large catchment area in its nearby outcrop, where it overlaps the Wilcox. The Wilcox sand is a nearly discontinuous deposit in three east-west tortuous ancient channels truncated near the

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middle of the camp by a north-south reverse fault. The cones of depression in it are extensive and irregular and the coefficients of transmissibility and storage range widely. It yields less water than the Claiborne but its water is of better quality, and has therefore been developed to economic maximum.

The Camp Van Dorn water supply comes from four aquifers within a Miocene deltaic mass. Most wells are in a sand at the base of the Homochitto member of the Pascagoula formation, which crops out 15 miles up-gradient and north of the camp. Large undeveloped supplies remain.

The water levels at Camp Shelby declined for six months and then remained nearly stationary for more than a year. No outcrops of the Miocene water-bearing sand could be found, but recharge occurs from the Pleistocene gravels in nearby river valleys.

The paper is based on ground-water investigations made in cooperation with the Mississippi State Geological Survey.

SALT-WATER ENCROACHMENT IN LIMESTONE AT SILVER BLUFF, MIAMI, FLORIDA.

RUSSELL H. BROWN AND GARALD G. PARKER.

Silver Bluff is part of a low coastal ridge that averages approximately 10 feet above sea level. It is composed of oölitic limestone to a depth of 20 feet which is underlain by coral limestone, calcareous sandstone, and sandy limestone of extremely high permeability to a depth of 120 feet. Shelly sandy marl of low permeability occurs from 120 to 160 feet and relatively impermeable clayey, silty marl occurs below a depth of 160 feet.

Construction of drainage canals was begun about 1910 and as a result the water table has been lowered several feet. This has allowed salt water to encroach inland 8,000 to 9,000 feet. A balance between fresh and salt water, in accordance with the Ghyben-Herzberg theory (1 : 40 ratio) appears to be established for a zone between the shore and 2,500 feet inland. Beyond this zone the contact between the fresh and salt water is lower than the theoretical surface computed on a 1 : 40 ratio. Either a balance has not been reached beyond 2,500 feet because of insufficient time since the water table was lowered by drainage, or a balance has been reached that is modified by seaward flow of the fresh water over the salty wedge.

ADIRONDACK AND HIGHLANDS MAGNETITE DEPOSITS.[1]

A. F. BUDDINGTON.

The United States Geological Survey has undertaken a program of geological studies in New York, New Jersey, and Pennsylvania with the objective of furthering the development of magnetite deposits in these states. Several different theories for the origin of the magnetite deposits of the Adirondack and the Highland districts are current in the literature. Some implications of these theories for the selection or rejection of areas for systematic exploratory work are discussed, especially with respect to their application to the Northwest Adirondack magnetite district.

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THE IRON ORE SITUATION IN THE WESTERN STATES.[1]

ERNEST F. BURCHARD AND CHAS. F. PARK, JR.

Geologic work begun by the U. S. Geological Survey on iron ore in the Western States is still in progress. Particular attention has been paid to deposits in areas tributary to manufacturing districts such as Puget Sound, Southern California, Northern Utah, and Pueblo, Colo. Preliminary reports available to Government War Agencies have been prepared on 3 deposits in Washington, 2 in Oregon, 2 in Idaho, 3 in Montana, 1 in Nevada, 3 in Utah, 9 in California, 6 in Arizona, 5 in New Mexico, and 2 in Colorado. In those 36 deposits, the largest of which are in California and Utah, more than 150,000,000 tons of iron ore are indicated by geologic work supplemented in certain instances by core drilling by the U. S. Bureau of Mines. Not all this ore is immediately available because of remoteness from transportation facilities and water supplies but these local disadvantages are not unsurmountable. These investigations have demonstrated the existence of larger ore reserves in the West than were formerly known, and encourage the belief that local reserves will suffice to supply for the duration of this War the iron and steel furnaces whose construction has been largely financed by Government funds.

MICA—MINING AND PREPARATION COST; 2nd PROGRESS REPORT.

B. C. BURGESS.

Colonial Mica Corporation price changes May 24th, 1943.
Increase in labor cost.
Development expense.
Amortization, royalty and depletion.
Revision of per ton costs. Revision of estimated recovery in pounds of run of mine mica per ton of rock.
Estimated 1944 costs.
Recommendations for increasing production.

EXPLORATION FOR ORE DEPOSITS—VIEWPOINT OF EDUCATION AND TRAINING.

B. S. BUTLER.

This paper discusses wartime educational conditions in school, in public surveys, in private institutions, in commercial organizations, in geological societies, and in geological journals. It outlines the education and training needed for the professional geologist contrasted with that permissible in cultural courses and for those who are not preparing as professional geologists. The necessity for retaining the scientific viewpoint is stressed, and some concern is expressed for the possible lack of that viewpoint immediately following the war.

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GEOLOGY OF THE QUICKSILVER DEPOSITS OF SOUTHWESTERN ALASKA.[1]

WALLACE M. CADY, ROBERT E. WALLACE AND EDWARD J. WEBBER.

Quicksilver deposits were first prospected in southwestern Alaska in 1906. Significant deposits in five promising areas have since been opened and several other encouraging localities are known over an area of about 20,000 square miles extending from Bristol Bay northward across the Kuskokwim River to north of the Yukon-Kuskokwim divide.

The geologic settings of the deposits are all similar. The predominant country rocks are steeply dipping, interbedded graywacke and shale intruded by basaltic type sills and by monzonitic to granitic stocks. The ore is localized principally in breccia zones between the sills and the less competent shale and graywacke, along bedding-plane joints, and more rarely in transverse fissures.

Cinnabar, stibnite and clay minerals including dickite fill openings lined with quartz; stibnite may replace some of the wall rock. Near the ore the sills are hydrothermally altered to a white rock, high in carbonate, silica, and clay minerals, which weathers yellowish brown and is a reliable guide in prospecting. Widespread placer cinnabar indicates that many more lodes await discovery in this little known region.

CHARACTERISTICS OF SOME NEW ENGLAND MICA-BEARING PEGMATITES.[2]

E. N. CAMERON, D. M. LARRABEE, A. H. MCNAIR AND G. W. STEWART.

Study of mica-bearing pegmatites in New Hampshire and Connecticut by Geological Survey parties has yielded much information regarding the structure of the pegmatites and the mode of occurrence of commercial mica concentrations within them. On the basis of mica occurrence, five principal types of deposits are recognized: (1) wall zone; (2) quartz core; (3) quartz pocket; (4) flash-joint; (5) disseminated. Structural and production characteristics of the different types will be discussed and applications of the data to mining and prospecting problems will be suggested.

FOUR UNUSUAL PEGMATITE MINERALS FROM MONTANA.

S. R. B. COOKE AND E. S. PERRY.

Four minerals from different parts of Western Montana, all having physical and optical properties which do not correspond exactly to those of described species, have recently been discovered. Properties, and spectrographically and chemically determined compositions are as follows:

Mineral A (found in pegmatite near Sappington) is radioactive, sp. gr. 3.95, hardness 5+, dark brown, resinous, conchoidal fracture, infusible with blowpipe, isotropic, lemon yellow in thin section, refractive index from 1.830 to 1.840. Essential elements are Cb (49.7% Cb_2O_5 + Ta_2O_5), Yt, Sc, U, Fe, with minor quantities of other elements.

Mineral B (found in placer near Laurin) is radioactive, sp. gr. 5.59, hardness 6, jet black, conchoidal fracture, infusible with blowpipe, isotropic, dark brown in thin section, refractive index 2.120 ± 0.005. Es-

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[2] Published by permission of the Director, U. S. Geological Survey.

sential elements are Cb, Sc, Yt, Sm, Dy, U, Fe, with smaller quantities of other elements. Probably fergusonite.

Mineral C (found in placer near Whitehall) is not radioactive, sp. gr. from 3.90 to 3.91, hardness 5+, jet black, uneven to conchoidal fracture, fuses easily with intumescence to a black slag, light brown in thin section, biaxial negative, α1.769, β1.795, γ1.805, $2V = 60°$, dispersion weak, pleochroic $-X$ light brown, Y brown, Z very dark brown, almost opaque. Essential elements are Ce, Fe, Si, Ti, P, Al, Ca, with rare earths. Possibly an allanite.

Mineral D (found in pegmatite near Butte) is not radioactive, sp. gr. 3.99, hardness 5½, jet black, conchoidal fracture, fuses easily with intumescence to a black slag, light brown in thin section, biaxial negative, α1.781, β1.802, γ1.810, $2V = 40°$, dispersion strong, $r > v$, pleochroic $-X$ light straw-brown, Y brown, Z very dark red-brown. Composition the same as the previous mineral. Possibly an allanite.

BERYL, ITS SOURCES AND USES.

EUGENE H. DAWSON.

Foreword: A short description of the recovery of beryllium, its properties and uses, as an introduction to the main subject, beryl.

Beryl:

1. The main sources of beryllium from its principal minerals beryl, crysoberyl, phenacite, helvite and idocease, together with particulars of their beryllium content and relative importance.
2. The sources of the foreign supply of beryl and quantities imported showing the increasing importance of beryllium in the last few years and the jump in consumption due to war industries.
3. The sources of beryl and beryllium minerals in the United States, their present production and potential reserves.
4. The work of the Geological Survey in locating the beryl-bearing pegmatites of the United States and the assistance of the Bureau of Mines in prospecting same.
5. Method of determining the beryl content of pegmatite dikes with a discussion of the determination of beryllia (BeO) by chemical analyses by spectrograph and by grain count.
6. Work done on the concentration of beryl by sink and float and flotation methods.
7. A discussion of the future of beryllium and the potential sources of supply, foreign and domestic.

FOREIGN WORK BY THE GEOLOGICAL SURVEY, U. S. DEPARTMENT OF THE INTERIOR.

JOHN VAN N. DORR, 2D.

The Geological Survey has been engaged, since 1940, in the investigation of mineral deposits in Latin America under the auspices of the Interdepartmental Committee for Cooperation with the American Republics on funds provided by the Department of State and by the Foreign Economic Administration. Geologic work in Argentina, Brazil, Bolivia, Venezuela, Panama, Costa Rica, Cuba, Jamaica, Haiti, and Mexico are discussed. The relations between this work and that being carried on by other agencies of the Government in the mineral field are mentioned.

SOME LESSER KNOWN PROPERTIES AND USES OF PHOSPHATES.

CHARLES B. DURGIN AND WOLDEMAR A. WEYL.

Most of the better known uses of phosphates are based on their distinctive chemical properties. It is the aim of this paper to point out a few of the lesser known properties and uses of phosphates where the chemistry of these compounds plays only a secondary role but where the characteristic features are brought about by the geometry of the atomic structure.

1. Certain phosphates form long chain molecules which have many properties in common with the high polymers of organic substances. The preparation of a rubber-like complex phosphate is described and its structure discussed.

2. Phosphorus pentoxide as well as many phosphates form glasses. The structure of these glasses is compared with that of silicates. Several properties and applications of these phosphate glasses are discussed.

Among the crystalline phosphates, the natural and artificial minerals possessing apatite structure are particularly stable. Based on the tendency of phosphates to form apatite and the stability of the latter the following uses are briefly discussed: Defluorination of water, apatites as host lattices for fluorescent materials and opacifying agents for milk glasses.

NEW POTASH DISCOVERIES IN UTAH.

B. W. DYER.

In 1924, the Crescent Eagle Oil Company, while drilling in the Paradox formation about seven miles west of Thompsons, Utah, secured cuttings which differed in appearance from sodium chloride and which, when analyzed, showed potassium both as the minerals sylvite and carnallite. The drilling was such that little was learned of the thickness of the potash beds but the analyses gave reason to believe that the hole had encountered a relatively rich and thick bed or beds of potash. The news spread rapidly, resulting in the entire area for a distance of thirty miles long and several miles wide being more or less covered by potash prospecting permits. Little actual drilling for potash was done and the holes encountered nothing as they were too shallow. However, several oil wells were drilled in various parts of the district and the cuttings from these showed that potash probably extended over a large area. The cuttings indicated deposits ten to over a hundred feet in thickness with a high content of magnesium. Until recently, this information had not been published and all interest in the area was lost so far as potash was concerned.

However, in 1942 public attention was again revived owing to the high content of magnesium which was discovered to be present in the form of the double salt, carnallite ($KMgCl_3 \cdot 6H_2O$). During the summer of 1942, the Defense Plant Corporation drilled a well to 4,200 feet which showed that between 3,318 and 3,539 feet there was 91.5 feet of salt with an average assay of 39.5 per cent carnallite; also, there were two sylvite sections, one between 3,419 and 3,518 feet and the other 4,152 to 4,157.5 feet. Since the completion of this well, four other wells have been drilled

to a depth of 5,000 feet and a general interest is being taken in the area extending from the D & RGW Railroad south to the town of Moab, Utah.

THE GEOLOGY OF THE MANGANIFEROUS IRON ORE DEPOSITS AT BOSTON HILL, NEW MEXICO.

LAWSON P. ENTWISTLE.

One of the important reserves of manganiferous iron ore is at Boston Hill, adjacent to Silver City, N. Mex. The area consists of a faulted block of gently dipping Lower Paleozoic shale, dolomite, limestone, and sandstone which have been intruded by a roughly circular mass of quartz-bearing monzonite porphyry and subordinate dikes. From a nose-like protuberance of the intrusion radiate many pre-mineral faults which have localized much of the hypogene mineralization.

Three important stages of hypogene mineralization can be recognized: (1) mesitite, a manganiferous iron magnesite, (2) quartz-sulphides, and (3) barite-galena. The carbonate stage is widespread but stronger near the intrusion. The quartz-sulphides stage is weak and largely confined to the area near the intrusion. The quartz may have been derived from hydrothermal alteration of the igneous rocks. Barite-galena is most important at the Chloride Flat mining district, about one mile north, where argentiferous galena provided silver for the supergene ore.

The hypogene carbonate has been oxidized by meteoric water, containing an excess of oxygen and carbon dioxide, to form ore bodies of intimately mixed hematite and pyrolusite which are largely confined to areas of brecciation and to spreads from faults in Silurian dolomite beneath soft Devonian shale.

GEOLOGY APPLIED TO MILITARY TACTICS.

HOMER D. ERWIN.

There has been much agitation since the beginning of the present world war for more extensive use of geology in military operations. It is recognized that geology can be applied widely to a war effort generally but the total concern in the present paper is the application of geology to military tactics, either for the offensive or defensive. Certain vital geologic conditions which can be all important to military installations and maneuvers and their relation to other factors of strategy in war are given.

To make the fullest use of geology it is recommended that there should be a regular military geologist for a certain number of men under arms. These men should constitute part of each regimental staff command in the field and supervise the collection, interpretation, map and report compilation, records and recommendations from a geologic standpoint for the regimental command, in conjunction with data furnished by other scientific branches of the service.

The duties and qualifications of a military geologist are pointed out. The demand for more instruction in military geology is emphasized as well as an appeal for the more extensive use of military geologists in our ranks by the high command, on the world battlefields.

A fairly complete bibliography of writings to date is given, which consider most specifically geology in field war operations.

MINERALOGY AND PETROLOGY OF THE CURRANT CREEK MAGNESITE DISTRICT, NEVADA.[1]

GEORGE T. FAUST AND EUGENE CALLAGHAN.

Relatively small deposits of dense, white, cryptocrystalline magnesite occur in Tertiary volcanic tuff in White Pine and Nye Counties 30 miles southwest of Ely, Nevada. Though the deposits are small, some of the magnesite is of very high quality with almost no iron nor aluminum. Much of the magnesite is mixed with dolomite and calcite, and a serpentine-like mineral occurs in one of the deposits in sufficient abundance to be of possible use in ceramics.

The tuff, ranging in thickness from a few feet to over 400 feet, occurs between two groups of flows. The lower group is mainly latite but near the top contains a hypersthene andesite of basaltic habit. Perlitic hypersthene-hornblende dacite also occurs in this group. The flows overlying the tuff consist of porphyritic quartz latite and are capped by massive latite crystal tuff. The tuff containing the magnesite has both vitric and crystal tuff elements together with reworked volcanic ejecta cemented by calcite to form a tuffaceous limestone. In scattered areas the tuff has been altered by solutions rich in magnesium and carbonic acid to dolomite, magnesite, magnesium silicate, and calcite. Mineral and chemical characteristics are the same throughout the sequence, suggesting that all rocks have been derived from the same parent magma.

THE ROOFING GRANULES INDUSTRY IN PENNSYLVANIA.

RICHARD M. FOOSE.

Three companies are engaged in the manufacture of roofing granules in Pennsylvania. The materials they use and the process of milling of these materials to prepare roofing granules are described and discussed briefly for each of the companies in this paper.

(Complete flow-sheets of the three mills will be shown by projection.)

THE TAXCO MINING DISTRICT, GUERRERO, MEXICO. A PRELIMINARY PAPER.

GEORGE M. FOWLER, ROBERT M. HERNON, AND EDWIN A. STONE.

Taxco is among the oldest mining districts in North America. Placer tin was mined there early in the sixteenth century and again, scantily, in 1943. The discovery of silver and associated minerals apparently occurred in 1549. The periods of greatest mining activity were, first, 1570 to 1585, second and most important, about the middle of the seventeenth century when many silver mines were worked by the La Borda brothers. Mining operations practically ceased in 1802 when an earthquake destroyed the waterpower sources. Some higher grade silver-bearing ores were mined later, but the complex ores remained intact until about twenty

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years ago. Present increased activities commenced in 1941, and the production now approximates 1,000 tons of ore daily.

The exposed country rock is schist with a little interbedded slate and a few dikes and sills, all regarded as pre-Cambrian, limestone, and slate which are thought to be Cretaceous, and more recent volcanics. A large overthrust separates the sediments from the schist basement.

The veins are continuous from the schist into the sediments. Most of them outcrop, strike northerly-southerly, dip steeply, and are mined through adits. The workable veins vary in width from one meter to several meters. The relief in the mining area exceeds 300 meters.

The ore minerals are galena and sphalerite and their oxidized products, a small amount of chalcopyrite, and numerous other minerals. Appreciable values in gold and silver are present in parts of some veins. The principal gangue minerals are pyrite, quartz, and calcite.

THE ZINC DEPOSITS OF THE GROUNDHOG BASIN, WRANGELL DISTRICT, SOUTHEASTERN ALASKA.[1]

H. R. GAULT.

The zinc deposits of the Groundhog Basin are on the mainland of southeastern Alaska about 13 miles east of Wrangell.

The ore-bearing beds are in a belt of gneisses and schists and are near a mass of granitic rock. Dikes and sills intrude the granitic body, and the geneisses, and schists. The bedding and cleavage coincide and the dip is about 65 degrees.

The ore was formed by replacement of at least four beds in the metamorphic section and is of two general types; sulfide ore and silicate ore. The sulfide ore is principally pyrrhotite, sphalerite, galena, and chalcopyrite. The silicate is sphalerite and other sulfides disseminated in gneiss.

The ore-bearing beds have been traced for about 4,500 feet through a vertical range of about 1,900 feet. Three quartz-porphyry sills are closely associated with the beds. An extensive broken zone lies between the upper two, or main ore beds to the north and below them to the south. The broken zone and certain small faults are silicified and fluorite is a conspicious constituent above an altitude of 2,500 feet, approximately the same altitude at which the sulfide ore grades upward into silicate ore.

No ore has been produced from Groundhog Basin. The sulfide ore in the main beds extends for about 1,300 feet with average widths of more than 3 feet. About 25 per cent of the upper bed and 60 per cent of the lower bed is lean ore or waste. The extent of the sulfide ore to the north and in depth is not known but the amount of ore may be much larger than is now estimated. The sulfide ore contains about 8 per cent zinc; 1.5 per cent lead; and 1.5 ounces silver per ton. The silicate ore is about twice as wide as the sulfide ore.

QUANTITATIVE STUDIES OF SOME ARTESIAN AQUIFERS IN TEXAS.

W. F. GUYTON AND N. A. ROSE.

Large quantities of ground-water have been pumped for many years in Texas from formations of Cretaceous, Eocene, Miocene, Pliocene, and

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Pleistocene age. Declines in water levels have resulted and investigations have been made by the Geological Survey in cooperation with the Texas Board of Water Engineers to determine the capacities of the formations to yield water to wells. The most reliable index of the quantity of water that a formation will yield has heretofore been considered to be the empirical correlation of pumpage and water levels in wells. Studies of recharge, laboratory studies of permeability and specific yield of water-bearing materials, and measurements of specific capacities of wells have also proven valuable.

With the development of new methods, pumping tests have recently come into use. A pumping test and the use of its results are essentially a process of obtaining for the formation under investigation the equation of a water-level drawdown curve for a short period of time and extending the curve over a longer period by means of the equation. Predictions may thus be made of drawdowns caused by given rates of pumping. In making the predictions computed drawdowns must be adjusted for boundaries and changes in character of the formation not taken into account by the equation determined with the pumping test. Pumping tests have been made at Houston, Lufkin, Camp Swift, South Camp Hood, North Camp Hood, and Sweeney. The methods of making the tests, the results, and the use of the results are briefly described in this paper.

MINERALOGY OF THE COPPER ORES AT THE MATAHAMBRE MINE, CUBA.

BERNHARD K. HAFFNER.

The Matahambre ore occurs in a number of structurally different ore bodies, but in general the ore bodies can be divided into two groups, namely (1) those associated with an east-west (Beta) fault system and structurally related faults, and (2) those associated with a northeast (Manacas) fault, and minor related faults. These two groups differ mineralogically in the proportions of the minerals present, and in the sequence of deposition.

In the Manacas type of ore the minerals present, in their general order of deposition, are quartz, pyrrhotite, siderite, pyrite, chalcopyrite, sphalerite, quartz, and ankerite. Pyrite and quartz are predominant in most of the ore.

In the Beta type of ore there occurs pyrite, quartz, ankerite, sphalerite, bornite, chalcopyrite, and quartz, usually deposited in that order. Chalcopyrite is the predominant mineral.

In both types of ore, overlapping, minor reversals, and omission of some of the minerals are common. In certain ore bodies near the junction of the Beta and Manacas fault systems, the ore shows a complicated mixture of the two types of mineralization. The Beta type of mineralization is later than the Manacas type, and follows or overlaps the last part of the Manacas mineralization, and in most places replaces it almost entirely.

Periods of fracturing during mineralization are clearly evident in both types of ore, and in the mixed ore bodies a study of the time relationship of the periods of movement on the two fault systems affords a check on the structural history inferred from the field relationships.

FACTORS IN THE LOCALIZATION OF MINERALIZED DISTRICTS.

CARLTON D. HULIN.

The Mining District, so well known to the economic geologist and mining engineer, and regarded by many as merely a convenient geographic subdivision in which ore deposits occur, must be recognized as constituting a geologic entity.

In regions of shallow erosion, epithermal deposits present are typically clustered in mineralized districts of limited areal extent. Localized in these same areas, favorable structural disturbances occurred coincident in time with the mineralization. Frequently the district is also the locus of injection of a dike swarm closely related in age to the mineralization.

In intervening areas, mineralization, structural disturbances of mineral age, and dikes comparable to those of the mineralized district are absent or only sparsely represented.

In regions of deeper erosion, the concurrence in time and areal distribution of igneous intrusion, mineralization and favorable structural disturbance is equally apparent. A central stock with attendent satellitic dikes frequently occurs. Ore deposits are clustered in and about the central intrusive, with structural disturbance of mineral age showing similar areal restriction.

In regions of still deeper erosion, where portions of batholithic bodies are exposed, the localization of mineralized areas is less well marked, but even here the time and space association of satellitic dikes, of structural disturbance, and of mineralization is apparent.

Igneous intrusion, structural disturbance and mineralization, which are so habitually concomitant within our mineralized districts, must be regarded as normal events in a cycle which commences with plutonic igneous invasion and ends with the period of mineralization. Certain events in this cycle, particularly those relating to the structural disturbances which have localized our mineralized districts, are discussed in detail.

THE HARDING BERYLLIUM–TANTALUM–LITHIUM PEGMATITES, TAOS COUNTY, NEW MEXICO.[1]

RICHARD H. JAHNS AND LAUREN A. WRIGHT.

The Harding pegmatites of western Taos County, New Mexico, though generally known as sources of spodumene and lepidolite, have become during the past year the foremost domestic source of the vital war metal tantalum, with a production of nearly 4 tons of concentrates containing 71 per cent Ta_2O_5. The chief tantalum mineral is microlite, but appreciable amounts of tantalite-columbite and hatchettolite also are present. More than 500 pounds of coarse tantalite-columbite—averaging 45 per cent to 55 per cent Ta_2O_5—has been recovered from small placer deposits tributary to the pegmatites.

The pegmatite of principal interest is a dike that lies within a zone of thrust faulting in steeply-dipping metamorphic rocks of pre-Cambrian age. It dips southward at a very low angle, has an average thickness of 50 to 55 feet, and is known to contain beryllium, tantalum, and lithium minerals for distances of 350 feet along the strike and 650 feet down the

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dip. This dike is strikingly layered, each layer consisting of a distinct rock type whose relative position within the dike is remarkably consistent, although a given layer may show considerable variation in thickness. This zoning has been a helpful and a reliable guide for recent predictions of ore-mineral distribution.

Most of the beryl occurs in two marginal zones of quartz-microcline-albite-muscovite pegmatite, one along the upper and the other near the lower contact of the dike. Twenty tons of high-grade beryl has been handsorted from a small portion of the hanging-wall layer. A large body of microcline-spodumene-quartz-mica-plagioclase rock which contains minor tantalum minerals lies below a well-defined quartz layer in the central portion of the dike; replacement of the microcline and spodumene by lepidolite has yielded several large bodies of lithium ore. Most of the high-grade microlite concentrations occur in spodumene-quartz-purple muscovite rock which lies above a zone of strong albitization in the lower half of the dike.

KNOWLEDGE OF METAL RESERVES IN THE WESTERN UNITED STATES.

AUGUSTUS LOCKE.

The armament function of our waning Western metal presses powerfully toward knowledge of reserves in the ground. But these reserves, down in the second and third mile of depth, out in extensions far under barren cover, and even in unknown and unimagined new districts, involve formidable questions and require grand compilations and wholesale new mapping for the prophesy of carriers and traps.

For this, private companies will enlarge their views and bureaus and schools will transfer the core of their work to the field. Obstacles will yield to the bigger purpose. If current institutions find the change too hard, others will come to relieve them.

PROBLEMS OF THE PERENNIAL YIELD OF ARTESIAN AQUIFERS.

O. E. MEINZER.

This paper is introductory to several following papers on the same general subject. It summarizes the development of quantitative methods relating to artesian aquifers and the problems that remain unsolved. The water yielded by artesian aquifers is derived mainly from two sources —(1) lateral percolation and (2) removal from storage with release of the artesian head and consequent compression of the aquifer and associated strata. Therefore quantitative studies of artesian aquifers involve (1) the coefficient of transmissibility, and (2) the coefficient of storage. The removal from storage proceeds gradually with lowering of head, and, hence, if a well is pumped or discharges by artesian flow, an indefinite period must elapse before equilibrium or steady-flow conditions are attained. The non-equilibrium formulas recently developed for discharging-well methods are applicable prior to attainment of steady-flow conditions, and some of them give coefficients of storage as well as coefficients of transmissibility.

The discharging-well methods have been put to much practical use in connection with water supplies for war purposes. However, perennial

supplies involve problems relating to the long-term coefficients of storage and the encroachment of salt water. There is evidence that the long-term coefficient of storage is much greater than the coefficient determined in pumping tests, and thus interpretation based on short-term coefficients may assign to recharge much of the water that is being taken from storage through the lag in compression of the aquifers and associated strata. This may suggest the eventual depletion of some artesian supplies comparable to the exhaustion of oil fields. The encroachment of salt water may also forecast the eventual depletion of the supplies.

THE RECOVERY OF PYRITE FROM COAL MINE REFUSE.

DAVID R. MITCHELL.

Several hundred thousand tons of recoverable pyrite are wasted each year at coal mines in the United States. Laboratory test data and operating data of a recent mill installation are cited, showing that a satisfactory grade of pyrite can be made for sulphuric acid manufacture. The overall economics at the present time are not favorable for the widespread installation of equipment to recover pyrite from coal mine refuse.

GEOLOGIC PROBLEMS AT LIMESTONE DAM SITES IN THE TENNESSEE VALLEY.

BERLEN C. MONEYMAKER.

Several of the large dams on the Tennessee River and its tributaries are founded on limestones. Although the foundation problems encountered in the course of construction are not identical at any two dam sites, solution cavities constitute the major geologic problems at all limestone sites.

All limestones in the Tennessee Valley are to some extent cavernous, regardless of the degree of their chemical purity, the complexity of the geologic structure, or the positions of present or past water tables. The size, form, abundance, and downward extent of cavities depend upon the local geologic structure, the presence of insoluble or impervious strata in the limestone, and the post-Cretaceous history of the region. Cavities may be small or of cavernous dimensions; they may be above the present water table or as much as 300 feet below the bedrock channel of the Tennessee River. They may be partially or completely filled with clay, silt, sand, gravel, cobbles, or boulders, or may be water-filled conduits.

The presence of cavernous rock at a dam site presents numerous problems, of which bearing strength and watertightness are paramount. Where the cavities are large and extend to considerable depths below the surface, dam sites are best abandoned in favor of less cavernous ones unless the locations are rigidly fixed by engineering requirements. Sufficient bearing strength may be obtained by deeper excavation than would otherwise be necessary. Watertightness may be attained by mining out the filling of large cavities, either by open-cut methods, by tunneling, or through large diameter core borings and filling them with concrete. The small filled cavities are washed with a jet of air and water under high pressure and grouted with a cement slurry or some other suitable material under the proper pressure.

SOME RECENT DEVELOPMENTS IN THE CANADIAN MINERAL INDUSTRY.

E. S. MOORE.

The Canadian mineral industry has, except for gold mining, been operating at a peak. Extensive development of mining and metallurgical plants to permit an increase of 50,000,000 pounds of nickel to the already high annual production is almost complete. The petroleum field at Norman Wells in the Northwest Territories has been considerably extended in connection with the "Canol" Project. The great fault in the Pinchi Lake Mercury Belt in British Columbia has been traced for a length of about 155 miles and cinnabar has been found along it in at least fifteen localities. One new mercury mine is coming into production 100 miles from the original discovery. A large low grade chromite deposit on the Bird River, Manitoba, has been tested. An important new gold deposit has been proven on Snow Lake, Manitoba. A new molybdenum deposit is producing in Quebec and very important muscovite pegmatites are now being mined in Ontario. Several iron deposits, two of which can furnish high grade lump hematite, are almost in position to produce ore in Ontario.

INVESTIGATIONS OF MERCURY DEPOSITS BY BUREAU OF MINES, U. S. DEPARTMENT OF THE INTERIOR.

MCHENRY MOSIER.

Mercury is one of the strategic metals the supply of which has been raised from critical uncertainty to more than enough for essential demands. Work by the Bureau of Mines has contributed substantially to increased production of mercury in the United States and to consequent accumulation of Government stocks. Other contributing factors were higher prices for mercury and Government loans to operators. The Bureau has undertaken 13 exploration projects, 10 of which have been completed. This work comprised 28,376 feet of several types of drilling and 23,798 linear feet of surface trenching and has indicated commercial ore containing 34,800 flasks of mercury and marginal ore containing 26,200 flasks, a total of 61,000 flasks, equivalent, respectively, to domestic production for 8 months, 6 months, and 14 months.

As Government stocks are now adequate, domestic production (currently at the rate of 50,000 flasks per year) is gradually being curtailed through Government control of labor and operating supplies.

QUARRYING METHODS OF THE BARRE, VERMONT DISTRICT.

WILLIS P. MOULD.

Granite stocks rising from the batholith underlying 150 sq. miles in the eastern section of northern Vermont have long supplied some of the highest grade building and monumental stone produced in New England. Quarrying began in the decade before 1800 to produce millstones, doorsteps, window and door sills and linels, building foundations, hitching posts, gate posts and monuments.

A granite stock called Millstone Hill constitutes the legal Barre granite quarrying district. Over 70 quarries have been opened on this stock. The schist overburden has been removed by glaciation but the stock itself was only slightly reduced by erosion.

Difference between Sheet and Boulder quarries is pointed out and derivation of names given.

The essence of quarrying lies in the advantage taken of the structural features such as sheeting and jointing. Production of dimension stone of good pattern for further processing depends upon the strict observance of the grain structure and its full use in quarrying. Grain, run, rift, lift, head and hardway—the terms used—are defined according to their usage in the Barre District. Equipment used and development methods employed are detailed.

The sizes and shapes of dimension stone and sawblocks, as well as the special quarrying of mausoleum roof slabs, spires and columns, are treated. Quarrier's aim is to produce—1st, sawblocks, and 2nd, dimension stone.

The paper ends with a brief summary of the trends in operational practice and technical development.

MOLYBDENITE DEPOSITS AND PEGMATITES IN THE PREISSAC–LA CORNE AREA, ABITIBI COUNTY, QUEBEC.

G. W. H. NORMAN.

Promising molybdenite discoveries have been made in the Preissac La Corne area of Quebec, which may cause the area to become the most productive molybdenite district in Canada. Two properties in the area are developed to production stage—Indian Molybdenum Ltd., in Preissac Township, and Wartime Metals La Corne Molybdenite Project in La Corne Township. Besides molybdenite the area contains tantalite, beryl and spodumene-bearing pegmatites.

Two large granite masses of similar composition occur in the Preissac-La Corne area. The southern mass contains numerous quartz veins with, or practically without, molybdenite, and only negligible amounts of pegmatite whereas the northern mass contains a large amount of pegmatite and only minor quartz veins and molybdenite. A comparison of these two granite masses and their associated deposits suggests that the molybdenite deposits are the end products of the pegmatite stage of igneous intrusion. The emplacement of tantalite and beryl-bearing pegmatites is confined to a wide border zone about the northern granite mass. The border zone therefore offers the most favorable location for prospecting for these minerals.

Quartz veins are widely distributed in the southern granite mass and in places form en echelon systems which traverse the granite as if along zones of rupture. Molybdenite occurs in important amounts only in quartz veins near the margin of the granite and particularly in those veins that have been deformed after the introduction of molybdenite. The general controlling factor in the deposition of molybdenite is probably the intersection of zones of rupture or faulting with the granite contact which suggests that the search for molybdenite should be restricted to deformed or faulted parts of the granite contact.

MICA DISTRIBUTION IN WESTERN NORTH CAROLINA PEGMATITES.[1]

JERRY C. OLSON, JOHN M. PARKER, III, AND JAMES J. PAGE.

General studies of mica-bearing districts in western North Carolina, begun by the Geological Survey late in 1939, were continued intermittently throughout 1942. During 1943 this work was followed by detailed mine mapping, in the course of which attention has been directed especially to the distribution and associations of commercial amounts and qualities of mica within the pegmatite bodies. Although the pegmatites differ considerably in this regard, the distribution has been found not to be haphazard but fairly consistent variants of five or six structural types. Of these the more productive are: shoots adjacent to the walls, sometimes accentuated where rolls or changes in dip occur; streaks more or less centrally located within the pegmatite; rather uniformly disseminated deposits in small lens-like pegmatites; and concentrations along massive quartz bodies. The relationships of the grade and quality of the mica to the various structural types will be discussed.

STRUCTURAL RELATIONS OF THE COPPER DEPOSITS AT MATAHAMBRE, CUBA.

E. N. PENNEBAKER.

The copper deposits near Matahambre, Cuba, occur as thick veins and irregular pipes in the lower half of the San Cayetano formation. This great accumulation of sandstone and shale has a measured thickness of at least 30,500 feet. The ore deposits are 2½ miles distant from the nearest known occurrence of igneous rocks.

The mineralized zones are in the northwest limb of a major anticline where beds strike uniformly northeast and dip regularly northwest at moderate angles. This regularity is disturbed by a few drag folds with axial planes steeper than the bedding, by abundant "abnormal" drag folds with axial planes flatter than the bedding, and by twisted beds with distorted dip and strike.

Several groups of faults are classified according to their attitudes. These fall into three patterns, as follows:

1. Bedding faults were initiated but poorly developed in the mine area during folding. Relaxation permitted the initiation of steep tension fractures across the bedding.

2. Next, steep strike faulting took place, and the footwall of a master fault was shoved up. Movement was deflected onto bedding planes in the footwall of this fault.

3. Shear faults with lateral relief occurred in the third episode. Dominant east-striking shears, minor north-striking shears, tension fractures, and breaking related to further reactivation of bedding faults prepared the ground for mineralization.

The form and distribution of ore bodies was controlled by various combinations of faulting, fracturing, and brecciation. Five major ore zones were developed.

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GEOLOGY AND MINING PROBLEMS OF THE CONEMAUGH RIVER RESERVOIR.

SHAILER S. PHILBRICK.

The Conemaugh Flood Control Dam for the protection of Pittsburgh will be located on the Conemaugh River, the main tributary of the Allegheny River, 7.5 miles east, upstream of Saltsburg, Pa. A concrete gravity dam 1,300 feet long and 137 feet high above stream bed is proposed to provide a reservoir of 274,000 acre-feet, extending 17 miles upstream, limited in elevation by the town of Blairsville. The selection of the dam site was controlled by the extensive mines in the Upper Freeport coal immediately upstream from Saltsburg which was the downstream limit of dam site exploration. Geological and foundation conditions were developed by core borings at both the Saltsburg and Bow Sites of which the latter was selected. The planning and interpretation of the borings are discussed. Geological conditions affecting the relocation of 16.2 miles of the Conemaugh Division of the Pennsylvania Railroad were investigated. Tentative plans were developed for the protection of a large mine in the Pittsburgh coal which lies below reservoir level.

COLLOIDAL DEPOSITION OF CINNABAR.

JAMES P. POLLOCK.

The possibility of colloidal deposition of cinnabar has been neglected. In opalite deposits cinnabar exists in particles within or near the colloidal size range. Colloidal processes have been admitted operative in hot springs and low temperature deposits similar to most cinnabar deposits. Mercuric sulphide sols are stable to elevated temperature and pressure, and in nature are probably chiefly affected by the electrolytes in solution, dilution of colloid, and presence of protective colloids as silica. The stability of mercuric sulphide sols to electrolytes is measured and shown to be greatly increased by dilution and by the protective action of silica. Mercuric sulphide sols follow the Schulze-Hardy valency rule and therefore the precipitating power of complex mixtures of electrolytes can be roughly computed. The stability of mercuric sulphide sols is shown to be greater than the equivalent precipitating power of the electrolytes in a hot spring depositing mercuric sulphide. It is concluded that finely divided or earthy types of cinnabar are colloidally deposited.

THE WAR MINERALS INVESTIGATIONS OF THE GEOLOGICAL SURVEY IN ALASKA.[1]

JOHN C. REED.

The war minerals investigations of the Alaskan Branch of the Geological Survey in 1943 included the systematic study of 25 deposits or districts. Some of these projects consisted of the continuation of work started in 1942 or before and the rest were new investigations. In addition to the formal projects many brief examinations were made by a number of geologists for the collection of mineral-resource data and to gain information necessary for the effective planning of future activities.

A total of 39 geologists were engaged in the field work, which was guided

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by 5 supervisors, each experienced in the region in which he directed the examinations.

The activities included the study of deposits of molybdenum, zinc, iron, copper, chromium, nickel, quartz crystals, coal, tungsten, asbestos, graphite, tin, and quicksilver. The investigations were widely distributed over the territory as follows: 7 in southeastern Alaska, 5 in the Alaska Railroad belt, 3 in southwestern Alaska, 2 in the western Yukon region, 4 on Seward Peninsula, and 2 each in the Prince William Sound and Copper River regions.

GEOLOGIC OCCURRENCE OF RUTILE.

CLARENCE S. ROSS.

Rutile is being produced from primary deposits in the Roseland and Hanover areas of Virginia, and from Magnet Cove, Arkansas. Both of the Virginia areas are being operated by the American Rutile Company, and the Arkansas area by the Titanium Alloy Manufacturing Company.

The rutile in the Roseland area occurs as disseminations in a feldspathic rock (the Roseland anorthosite) where it was introduced by hydrothermal or vapor phase processes, subsequent to the formation of the enclosing feldspar rock. Granulation of this rock seems to have accompanied its introduction and facilitated the introduction of mineralizing solutions. Associated ilmenite formed by preference wherever iron was available, and rutile only where there was a minimum of iron in the intruded rock or in the mineralizing solutions.

In the Hanover area, the rutile occurs in a very finely-granulated feldspathic rock which has been partly kaolinized.

The rutile mine at Magnet Cove occurs in a volcanic agglomerate composed of rock fragments, among which an orthoclase feldspar is dominant, and with interstitial clay material derived from glassy volcanic ash. This agglomerate is cut by ferromagnesian dikes and numerous vein-like bodies of carbonates. Rutile and associated pyrite are later than all these, having formed in the interstitial clay, as veinlets in the feldspar rock, and in the carbonates.

Brookite, another of the titanium oxides, occurs abundantly in other parts of the Magnet Cove area but has not been commercially mined.

GEOLOGY IN MINING.

HARRISON SCHMITT.

The application of geology in mining today has several aspects: I. *The survey of a mining district by the state and federal governments.* This work is invaluable for correlations, but not exhaustive or current enough to be critical in most detailed ore finding problems. II. *The quick analysis and appraisal of a prospect or mine in any stage of development and/or exploitation.* This work requires the very highest skill and experience. III. *The use of geology in the actual detailed examination work after the preliminary appraisal has resulted in a decision to further examine.* The chief functions of this work are to set the pattern for the sampling and to guide preliminary exploration. IV. *The detailed geological work at a going mine.* Mapping methods are described and compared. Methods of integration of data are described. The training of geologists and methods of exploration are discussed. V. *The theoretical aspect.* The

last part of the paper lists and discusses some of the elements of geologic theory. So far as the immediate problems of ore finding go the emphasis necessarily must be put on the deposition of ore and the work is largely concerned with structural forms and their measurement, channelways, replacement phenomena and fault problems. The broader problems of ore finding are concerned with the whole theory of mining geology. Of especial interest are the problems of the form of the "central" intrusives, of extension in depth, and of the ultimate source of the metals.

MAGNETIC EXPLORATION OF THE BOHEMIA BASIN NICKEL–COPPER DEPOSITS, SOUTHEASTERN ALASKA.[1]

MATT S. WALTON, JR.

The Bohemia Basin nickel-copper deposits are segregations of pentlandite, pyrrhotite and chalcopyrite in a zone near the inward-dipping lower contact of a norite mass, part of a composite stock on Yakobi Island, Southeastern Alaska. Little was known of the deposits beneath a large muskeg-covered area, with only isolated exposures of sulfide-bearing norite, until the field season of 1943 when eight traverses were made in the covered area with an Askania vertical intensity magnetometer across the inferred position of the deposit. The deposit was detected definitely beneath six of the traverses, indicating that it is continuous beneath most of the covered area. Magnetic profiles are consistent with the hypothesis, proven at two places by outcrops and drill holes, that the deposit dips inward. The profiles and outcrops indicate that the deposit is about 75 feet thick. The profiles also suggest that the deposit under the covered area, extends down the dip for a distance greater than its thickness and that the muskeg cover is not deep. These inferences are consistent with available drill data. The inferred quantity of sulfide-bearing material in the deposits in the norite mass was increased as a result of the magnetometer work from 5,000,000 to 8,500,000 tons. The magnetic data will facilitate planning of any further development of the deposits and would have been useful in the more effective placing of some of the holes already drilled.

IRON DEPOSITS OF KASAAN PENINSULA, PRINCE OF WALES ISLAND, SOUTHEASTERN ALASKA.[1]

LAWRENCE A. WARNER.

High-grade deposits of magnetite, containing some copper, on Kasaan Peninsula, Prince of Wales Island, southeastern Alaska, lie within a mile of salt water at altitudes of less than 1,500 feet.

The deposits have been worked intermittently since 1900, principally for their copper content, and have yielded more than 600,000 tons of ore valued at more than $6,000,000.

The ore consists chiefly of magnetite with pyrite and chalcopyrite. The ratio of chalcopyrite to magnetite ranges widely, and locally the deposits are copper ore with minor precious metals. The major reserves are in iron ore and in the bodies examined the reserves are estimated to exceed 5,000,000 tons. The average ore tenor is about 50 per cent iron

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and 0.5 per cent copper. Phosphorous and titanium are virtually absent. The sulphur content ranges from a few hundredths of a per cent to about 4 per cent.

In 1942 the Geological Survey resumed a systematic study of the deposits which is still in progress. Topographic, magnetic, and geologic surveys have been made at most of the deposits which have been mined or prospected.

Some trenching, sampling, and diamond drilling have been carried on by the Bureau of Mines. Much of the peninsula has been only superficially prospected and it is anticipated that further work will reveal additional ore bodies.

THE PERENNIAL YIELD OF ARTESIAN WATER IN THE COASTAL AREA OF GEORGIA AND NORTHEASTERN FLORIDA.

M. A. WARREN AND H. H. COOPER, JR.

Heavy withdrawals of artesian water have created large cones of depression at Savannah and Fernandina and smaller cones at Jacksonville and Brunswick. Further expansion of the cone of depression at Savannah may cause saline water to move into the well fields. If a large part of the water withdrawn through wells is obtained from storage in the formation, the cone of depression will continue to expand with no increase in rate of withdrawal; otherwise it will be approximately stable. The coefficient of storage may be used to determine whether it is likely that a large part of the water is coming from storage.

The results of pumping tests indicate that the coefficient of storage is about 0.0003 at Savannah and Fernandina and about 0.02 at Jacksonville. If these are average for the respective areas, the cones of depression at Savannah and Fernandina are probably already approximately stable, but the cone at Jacksonville may expand further even though the rate of withdrawal is not increased. A coefficient of storage of 0.02 is, however, unusually high for an artesian aquifer, and further investigations may show it to be due to leakage through confining beds or some other cause.

The paper is based on investigations which are being made by the U. S. Geological Survey in cooperation with the Georgia Division of Mines, Mining and Geology and the Florida Geological Survey.

MICA IN WAR.

CAPTAIN R. G. WAYLAND.

Subjects to be discussed:

1. Qualities of mica of interest to the Army.
2. Trends in the supply from India.
3. Trends and problems in mica supply from Brazil and other foreign sources.
4. Domestic mining trends, and problems of mica classification and preparation.
5. The Army's conservation program and its effect.

PRELIMINARY REPORT ON LOCATING PEGMATITE BY AIRPLANE.

ROSCOE J. WHITNEY.

This paper in itself is practically an abstract of a detailed report to the New Hampshire Development Commission of progress to November 1943 on cooperative project with the New Hampshire Civil Air Patrol to determine the utility of aerial reconnaissance and its probable cost in the search for new pegmatite-bearing areas as well as its utility in checking more speedily, effectually and economically known pegmatite-bearing areas for locations now known or recorded.

No maps or photographs can be shown publicly because of wartime restrictions on aerial photography and the reproduction of large scale maps.

This paper is to be read as a record that such a detailed report will be on file at the New Hampshire Development Commission for future release when wartime restrictions are lifted and to inform institute members that the Civil Air Patrol can cooperate in the search for strategic minerals anywhere in U. S. and Territories.

RECENT DEVELOPMENTS IN ARIZONA METAL DEPOSITS.

ELDRED D. WILSON.

Recent developments in Arizona metal deposits are of interest chiefly from the standpoint of production of the five major metals, copper, zinc, lead, gold, and silver. Curves of the yearly production and metal prices during 1910–43 compare recent trends with those of the World War I and 1925–29 periods of high yield.

Yearly during 1910–43, Arizona led the United States in copper production. The amount of copper mined during 1939–43 exceeded that of the 1914–18 war period, but its value was some $300,000,000 less. Of the ten properties which yield 99 per cent of Arizona's copper, three—Morenci, Ajo, and Castle Dome—are open pit mines with a total combined capacity of more than 75,000 tons per day. Price premiums have stimulated mining, particularly of siliceous copper ores, from smaller properties.

Zinc mining in the State has increased since 1933. Of the nine principal zinc mines recently active, six are relatively new as zinc producers. In addition, there are smaller producers in several districts.

Most of the zinc mines are important producers of lead. The output of lead decreased during 1942–43.

The copper mines yield more than half of the gold and two-thirds of the silver normally mined in Arizona. Siliceous gold mines were largely inactive during 1943.

Government funds have financed large expansion programs, and small Government loans and premiums have subsidized production from some marginal deposits.

NONMETALLIC MINERALS SPEED THE WAR.

OLIVER BOWLES.

Nonmetallic minerals perform important functions in the war program. Cement was used in unprecedented quantities for constructing concrete

runways at airfields, military roads, dry docks, harbors, fortifications and many other military establishments, most of which are now completed. Mica is essential for radio condensers and airplane spark plugs, quartz crystal for communication systems, strontium for flares and tracer bullets, lime for a host of chemicals as well as for synthetic rubber and magnesium metal manufacture, asbestos for insulation on warships, mineral wool and vermiculite for heat insulation to conserve fuel, phosphorus for smoke screens, and industrial diamonds for precision machining. Even a commonplace rock like limestone is used in vast quantities as furnace flux to speed the output of iron. Phosphate rock, potash and nitrates are supplying fertilizers to increase greatly needed food supplies. Geologists are constantly finding new mineral deposits while engineers and technologists are promoting their most efficient utilization. Industrial minerals are being mobilized as never before in human history. Much progress was made in 1943 in improving processes for beneficiation of minerals and for their subsequent treatment. Nonmetallic minerals are applied in many new ways to conserve metals for direct military use. More detail on outstanding accomplishments in the field of nonmetallics during 1943 appeared in the February 1944 issue of Mining & Metallurgy.

STOPE FILLING AT THE BAKER MINE.

C. G. GRIM.

Mining Methods:
Description of Mining Methods in Baker Mine that are pertinent to the stope filling procedure.

Stope Filling Methods:
Brief discussion of original and present methods in general.

Underground Preparatory Work:
Description of work necessary to prepare stopes for filling.

Surface Drilling Procedure:
Description of drilling equipment and drilling practice.

Surface Filling Operations:
Description of equipment and methods of introducing fill material into the stopes on the surface.

Underground Filling Operations:
Necessity of developing method of efficient distribution of material in the stope. Description of sand slide and of the power wheel attachment. Operation of the slide throughout the filling operation. Discussion of Dust Control.

Water Shut-offs:
Method of making water shut-offs in completed drill holes.

Timber Cribs:
Use of timber cribs on top of fill for roof support.

Conclusion:
Economies of filling method.

SCIENTIFIC NOTES AND NEWS

J. B. STONE has recently been appointed general superintendent of the Fresnillo Co., Zacatecas, Mexico.

H. C. HORWOOD of the Ontario Department of Mines is geologist for Northwestern Ontario, a new District Geologist position created last May by the Ontario department. He spent the summer doing detailed areal geology and examining gold prospects in the Missanaibi area and has now opened an office in the court house, Port Arthur, Ontario.

W. F. JAHN, foreign mineral specialist of the U. S. Bureau of Mines, is acting chief of the mining division of Corporacion Promocion del Intercambio, Buenos Aires, Argentina.

D. M. LARRABEE is working on mica deposits for the U. S. Geological Survey at Spruce Pine, North Carolina.

LT. COLONEL O. G. BELL, former geologist for Humble Oil and Refining Co., is base executive officer of Peterson Army Air Field, Green Mountain Falls, Colorado.

W. B. HEROY has been transferred from director of reserves to director of the foreign production division of the P. A. W.

H. F. BAIN, who was adviser to the Commonwealth Bureau of Mines and interned in Manila in 1941, returned to the United States in December on the "S. S. Gripsholm."

E. B. BAILEY, F.R.S., has been awarded one of the two Royal Medals by the Royal Society for his distinguished contributions to the knowledge of mountain structure and his studies on the tectonics of vulcanism.

W. A. SEAMAN of the Michigan College of Mining and Technology has been appointed curator of the Mineralogical Museum named after his father, the late A. E. SEAMAN, formerly head of the department of geology of the college.

C. A. FULTON, president of the Southern Phosphate Corp., Baltimore, Maryland, has been elected president of the American Institute of Mining and Metallurgical Engineers for 1944.